Contract NAS9-14577
DRL Number T-1106
Line Item No. 3
DRD Number MA-183T
MCR-76-10
NASA CR-
147500

Final
Report

ZERO LIQUID CARRYOVER WHOLE-BODY SHOWER VORTEX LIQUID/GAS SEPARATOR

December 1975

Prepared for:

Lyndon B. Johnson Space Center
National Aeronautics and Space
Administration

Prepared by:

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(NASA-CR-147500) ZERO LIQUID CARRYOVER WHOLE-BODY SHOWER VORTEX LIQUID/GAS SEPARATOR Final Report (Martin Marietta Corp.) 148 p HC $6.00 CSCL 06K

N76-18790

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G3/54 18525

MCR-76-10 | Final Report | December 1975

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Approved by:

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Program Manager

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FOREWORD

This report was prepared by the Martin Marietta Corporation for the National Aeronautics and Space Administration, Johnson Space Center under Contract No. NAS9-14577 in accordance with Line Item #3 of DRL T-1106; covering the activity of paragraphs 3.2.1, 3.2.2, 3.2.3, and 3.2.4 of the SOW. The NASA Technical Monitor was Mr. Nicholas Lance, Jr. of the Environmental Control and Life Support Systems Branch.

ABSTRACT

This Final Report describes the effort accomplished under Contract NAS9-14577 in the development and evaluation of a liquid/gas vortex type separator design which eliminates liquid and semi-liquid (suds) carryover into an air recirculating system. Consideration was given to a number of soaps other than the "Miranol JEM" which was the low sudsing soap used in previous test runs of the NASA Space Shower.

Analysis of test parameters and prototype testing resulted in a revised separator configuration and a better understanding of the suds generating mechanism in the wastewater collection system. The final design of the new separator provides for a wider choice of soaps without leading to the problem of "carryover". Furthermore, no changes in separator-to-shower interfaces were required. The new separator was retrofitted on the NASA "Space Shower" and satisfactorily demonstrated in one-g testing at the Johnson Space Center, Houston, Texas.

SUMMARY

This document presents the results of analysis, development, and tests performed on a liquid/gas separator for the NASA Zero Gravity Whole-Body Shower Assembly. Analysis and development of the separator were in accordance with the Statement of Work for Contract NAS9-14577. Testing was in accordance with the plan submitted to NASA Johnson Space Center as "Attachment 1" to the Monthly Progress Report of October 1, 1975.

The study and development program was divided into four major tasks as follows:

Task 1 - Shower Water Collection System Performance Analysis;

Task 2 - Separator Design;

Task 3 - Fabrication and Functional Checkout;

Task 4 - Separator Performance Verification.

These tasks required analyzing various possible causes of sudsing or foaming that produce "carryover" of suds in the air stream; performing tests to identify and verify suspected causes; identifying acceptable separator parametric limitations, designing, building, and functionally testing a zero carryover vortex type liquid/gas separator; and verifying separator performance during evaluation with a variety of cleansing agents in the whole body shower.

During Task 1 the vortex liquid/gas separator (LGS) was analyzed in detail to determine the recommended refinements to the existing shower LGS to prevent suds and liquid carryover. Two approaches to the problem were followed. First the LGS was analyzed for means of reducing the soapy water agitation and thus preventing suds propagation. It was accomplished by reducing the velocity to its lowest acceptable level in the LGS and isolating the soapy water from the turbulent center core of the separator as fa as possible. The foregoing approach concerned itself with the formation of suds. The second approach is concentrated on breakdown of suds already present in the system and includes mechanical methods (such as pins), chemical defoamers, and alpha/beta ray generators to upset the balance of the

stabilized energy system of the bubbles.

On the basis of the foregoing analyses, recommendations for improvements to the LGS were made at the midterm design review. After approval of the recommended changes, a prototype separator was built and successfully tested at MMC. The changes and test results were subsequently reviewed with NASA representatives and approved for incorporation in the deliverable hardware. Mechanical/chemical approaches to suds breakdown were found unsatisfactory.

The Task 2 Separator Design effort was directed toward the production design of the deliverable hardware. The original drawings of NASA Contract NAS1-11339 were revised in order to incorporate all the approved changes. The interface dimensions were left as is in order to be compatible with the rest of the shower water collection system. No material changes were made with the exception of the substitution of Plexiglas for Lexan in the body of the LGS. This substitution was approved by NASA on the basis of the superior transparency characteristics of Plexiglas.

In all, five internal dimensional changes were incorporated to optimize the operation of the LGS. In addition, an alternate (deeper) sump configuration was developed to provide for a longer "dwell" time of the suds in the sump. This permits a more effective breakdown of the suds into liquid before being pumped out of the sump.

Task 3, the Fabrication and Functional Checkout, was in accordance with the drawings and the prototype testing respectively. A pressure leak test at 1 psi was satisfactorily accomplished at the conclusion of the fabrication phase. Then a functional checkout of the separator was conducted and the results were compared to those of the prototype and found to be quite similar. As in the case of the prototype, it was found that the addition of body oils (man in the loop) made a significant difference in the amount of suds generated. Therefore, a number of soaps were tested with actual showers taking place as part of the test setup. The separator was found to be ready for retrofitting and verification testing at NASA-JSC.

Task 4, Separator Verification Testing at NASA, was a retrofit and test program under actual shower operating conditions, i.e., with test subjects and various soap cleansing agents. In all, twenty-four test showers were taken with a choice of Ivory, Camay, Safeguard, or Olive Leaf (liquid) soap. All the test runs compared favorably with the previous prototype runs and good correlation of data was achieved. No visible "carryover" of suds or water was in evidence.

The new information and conclusions resulting from this contract are as follows:

1) The retrofit LGS effectively separates liquid/suds from air without "carryover".

2) Soaps which have been demonstrated are Olive Leaf, Ivory, Camay, and Safeguard. They cover the field of liquid, standard, beauty cream, and bactericidal soaps.

3) The vacuum pick-up head and flexible hose contribute much more significantly to suds generation than does the LGS itself. A movie film has been made to document this phenomena.

4) Wastewater which comes from actual use of a shower is much less likely to generate excess sudsing than simulated wastewater made up of tap water and soap. It is apparent that the body oil and salts tend to reduce the sudsing ability of soap/water solutions.

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INTRODUCTION

To date, space missions have had a small crew size, limited vehicle volume, and have had minimum provisions for personal hygiene. As mission duration, crew size, and volume of manned space missions increase, whole body bathing will be required to satisfy the physiological, psychological, and social needs of the crew members.

A whole body shower, designed to function in the absence of gravity, has already been constructed under previous NASA contract for this purpose. Water collection from the shower stall is accomplished by extracting air and water from the stall and separating the water from the air in a vortex separator. However, the present water collection system in the shower is restricted in the type of cleansing agents that may be used. Excessive foaming and ineffective separation occurs when "high sudsing" soaps are used.

Table 1 contains the baseline mission model requirements for which the shower was developed. It was the intent of this four task program to analyze the water collection system, improve the separator design to permit a wider selection of cleansing agents, build a new separator, and verify its performance as a retrofitted part of the existing whole body shower at the NASA-JSC. These objectives have been satisfactorily met.

Table 1 Baseline Requirements

MISSION MODEL	
Mission Duration, years	2
Resupply Capability, days	180
Gravity Mode, g's	0 to 1
Mission Objective	space station/space base
VEHICLE MODEL	
Compartment Size:	
(a) Diameter, m (in.)	3.96 (156)
(b) Height, m (in.)	2.08 (82)
CREW MODEL	
Number of Crewmen	
Height of man, m (ft)	1.83 (6)
Mass of man, kg (lb)	72.5-86.2 (160-190)
Metabolic Activity (zero-g)	150 percent
Average for 24 hours	basal matabolism rate
ATMOSPHERE MODEL	
Cabin Total Pressure Pa, mmHg (psia)	362 to 760.2 (7.0 to 14.7)
Gas Composition Pa, mmHg (psia)	181 (3.5) oxygen diluent nitrogen
Carbon Dioxide	
Partial Pressure, mmHg (psia)	0 to 3.0 (0 to .058)
Temperature (dry bulb) K (F)	291 to 296 (65 to 75) adjustable
Dewpoint, K (F)	281 to 287 (46 to 57) for any dry bulb temperature
FRESH WATER DELIVERED	
Quantity, kg/shower (lbs/shower)	3.6 (8.0)
Delivered H_2O Temperature, K (F)	314 $\pm$ 2 (105 $\pm$ 5)
Delivered Flow Rate, kg/sec (lb/min)	0.038 (5.0)
Delivered H_2O Pressure, Pa mmHg (psig)	1309 (25.32)

continued

Table 1 Concluded

WASTE WATER RETURNED (FROM SHOWER)		
Flow Rate, ml/sec (lb/hr)	40.0 (317) (maximum)	
Water Pressure	ambient (minimum)	
BLOWER AND AIR LOOP		
Type	Rotron Model SL2EA2	
Performance	see Figure 1	
System Configuration	see Figure 2	
Existing Shower Flow Rates (cfm)		
Air Injection to Separator	.00236 (1)	5.0
CO_2 Bleed	.00320 (2)	6.8
Shower Stall	.01321 (3)	28.0
Total Flow Delivered, m^3/sec (cfm)	.01877	(40.0 cfm)

(1) Required by current separator design.

(2) Necessary to maintain less than 3 mmHg CO_2 partial pressure in shower stall for estimated 0.25 hour shower.

(3) Must be adequate to remove water droplets from walls and floor in one-g field.

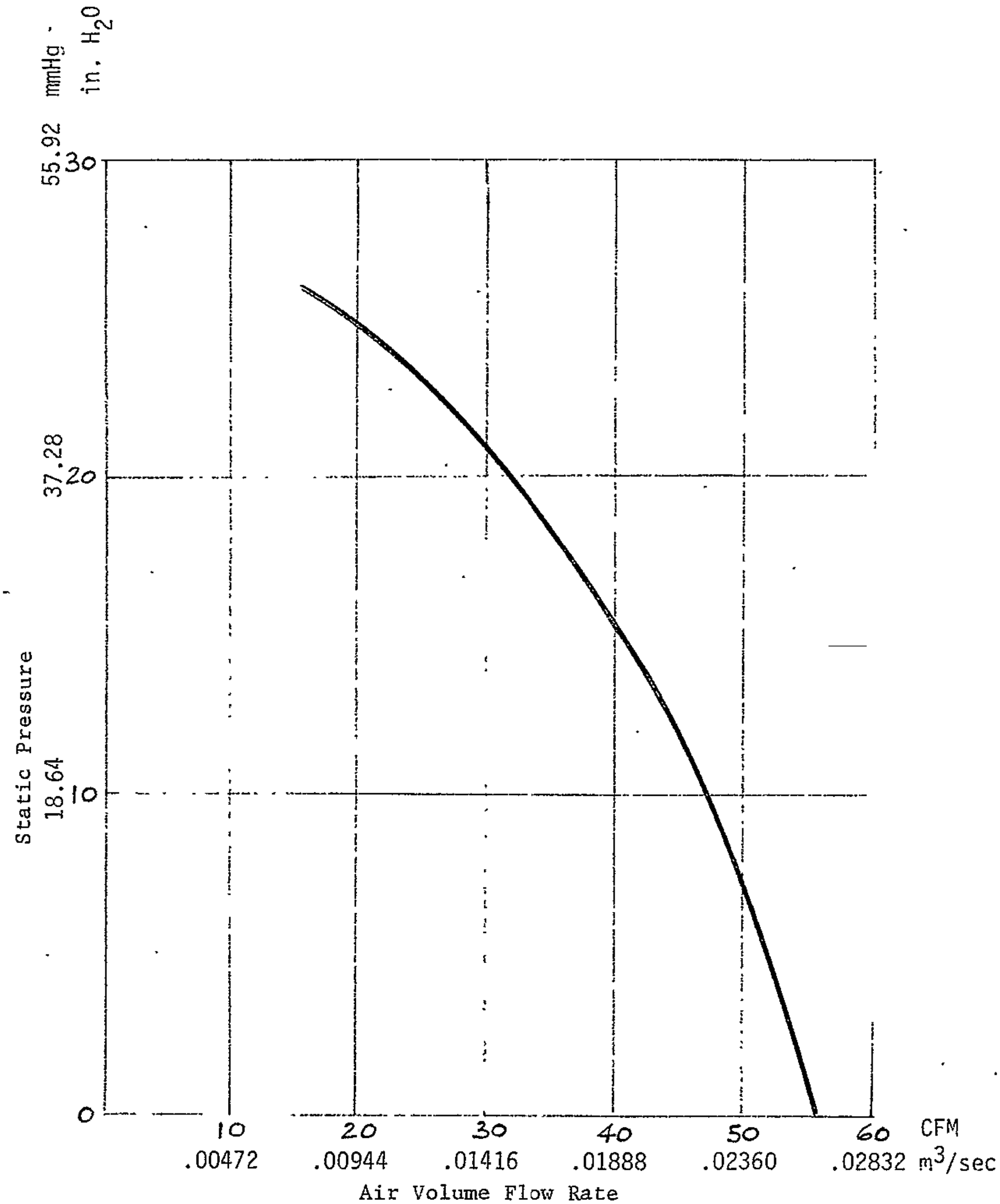


Figure 1 Static Pressure vs Flow Rate for Rotron Spiral SL2EA2 Blower

(1) Flow Meter
(2) Filter
(3) Pump
(4) Blower
(5) (7) (8) Orifice
(6) Heater
(9) Nozzle
(10) Pickup and Hose

* Development Test Elements

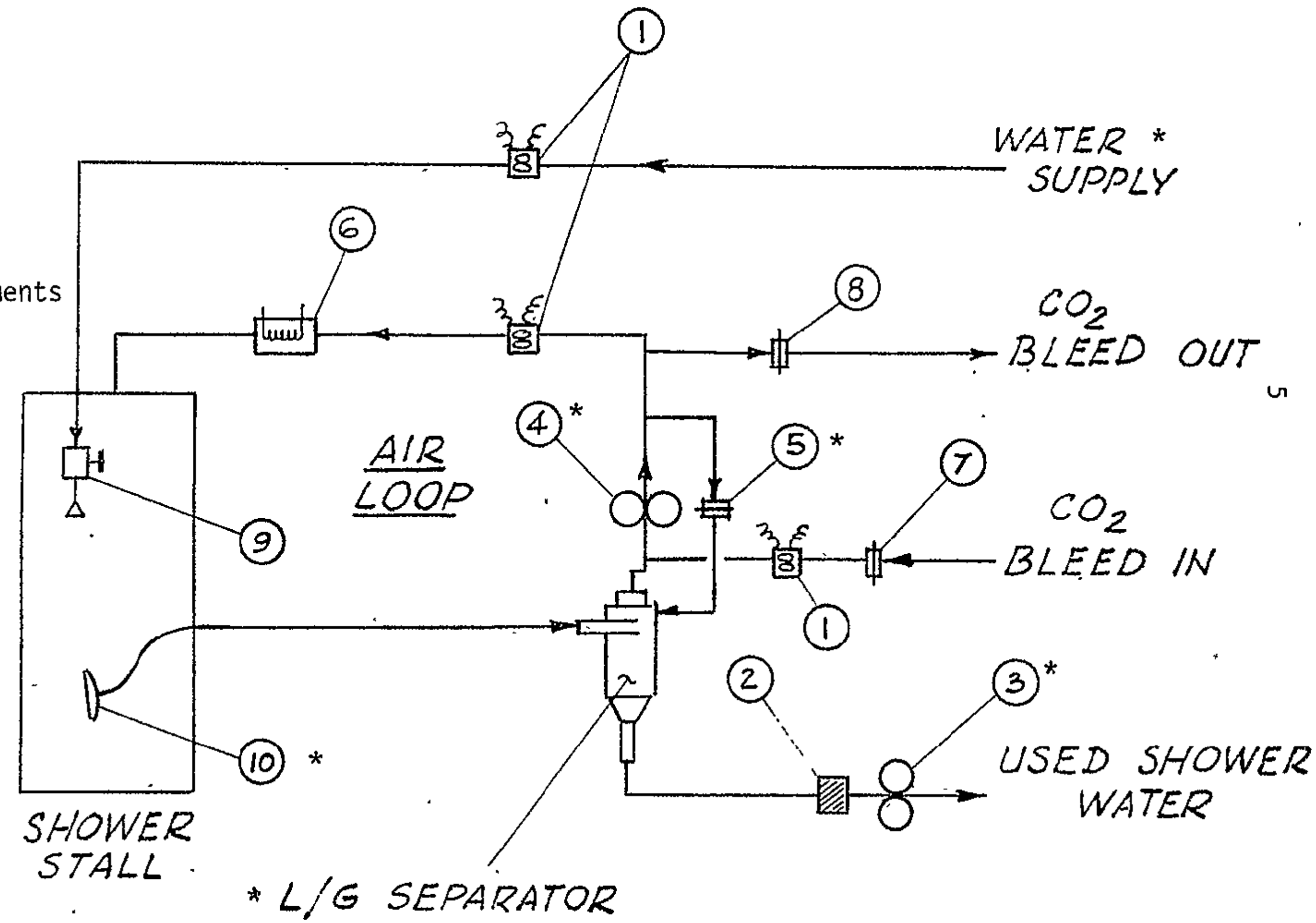


Figure 2 Zero Gravity Whole-Body Shower Flow Schematic

TASK 1 - ANALYSIS
SHOWER WATER COLLECTION SYSTEM PERFORMANCE ANALYSIS

The vortex LGS has been analyzed in detail to determine the recommended refinements to the existing shower LGS to prevent suds and liquid carry-over. Two approaches to the problem were followed. First the LGS was analyzed for means of reducing the soapy water agitation and thus preventing suds propagation. This can be accomplished by (1) reducing the velocity to its lowest acceptable level in the LGS and (2) isolating the soapy water from the turbulent center core of the LGS as much as possible. The first approach concerned itself with the formation of suds while the second approach is concentrated on breakdown of suds already present in the system. This second approach includes mechanical breakdown means (such as pins), chemical defoamers, and alpha/beta ray generators to upset the balance of the stabilized energy system of the bubbles.

The following discussion analyzes the configuration of isolated parts of the LGS for optimum liquid-gas separation and minimum water agitation. Optimum liquid-gas separation criteria has been developed and categorized and can be proportioned to the shower flow requirements. The water agitation can be minimized by keeping water and suds from the turbulent center section of the separator. This turbulent center core can be seen in Figure 3, which illustrates the path of the radial and axial air flow.

Two-Phase Inlet

The two-phase inlet must be sized to accept slugs of water and impart the proper velocity to the two-phase mixture to reach adequate separating centrifugal force in the body of the separator. Several inlet configurations have been tested including tangential, volute, and inlet with vanes. We have found the rectangular-shaped tangential inlet to be best (Ref. 1) in separator performance and in ease of fabrication. The rectangular shape provides for liquid coalescence and wall film flow. Dimensions "A" and "B" in Figure 4 define the choked area of the inlet. Several variations exist, but a height-to-width ratio of 2 performs consistently well (Ref. 2). From a previous series of $\pm$ one-g and zero-g tests, the Table 2 inlet velocities were established for optimum LGS performance.

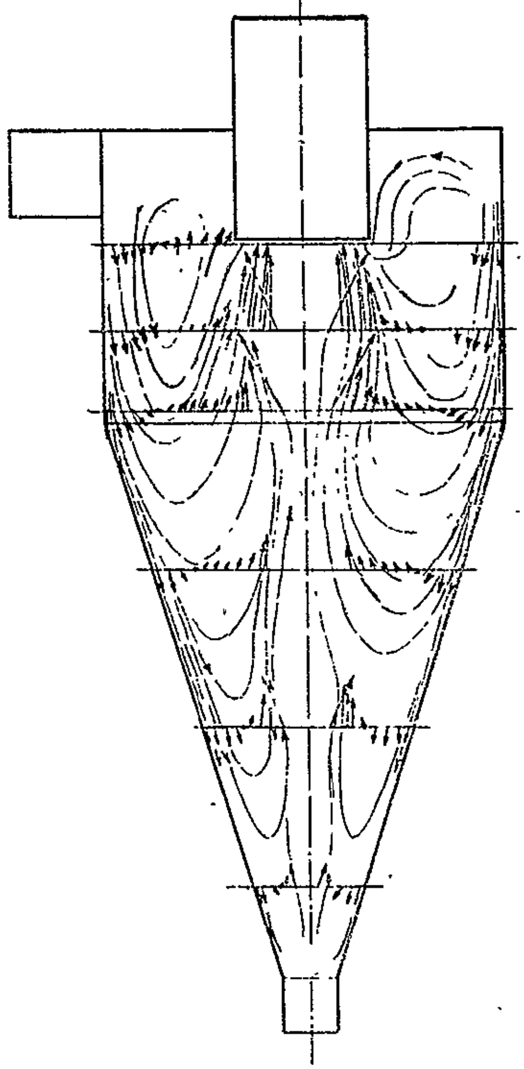


Figure 3 Radial and Axial Air Pattern

Table 2 Inlet Velocity

Environment	Inlet Velocity
Negative One G	32.5 - 41.4 m/sec (6400 - 8150 fpm)
Positive One G	13.21 - 28.2 m/sec (2600 - 5550 fpm)
Zero-G	13.21 - 28.2 m/sec (2600 - 5550 fpm)

A spiral ramp starting at the top of two-phase inlet and completing one revolution inside the body of the separator was found to be very beneficial in initiating the vortex flow. The ramp adds axial velocity to the two-phase mixture, reduces turbulence at injection point, and reduces total LGS pressure loss. The ramp width spans the gap from outer

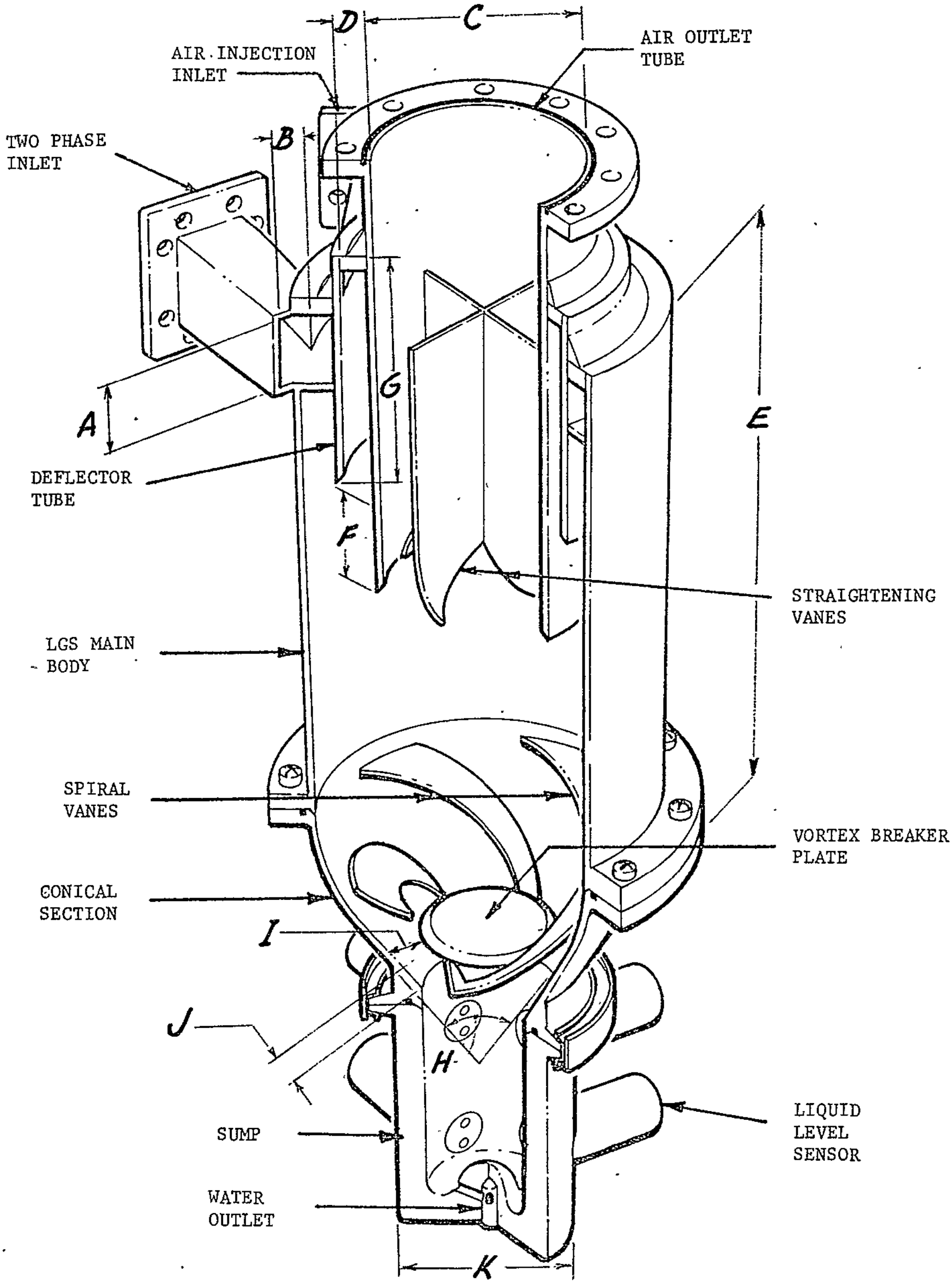


Figure 4 Elements of Vortex Liquid Gas Separator

separator wall to outer deflector wall. The pitch of the ramp is equal to the height of the inlet (dimension "A" in Fig. 4). The ramp makes one complete revolution at a constant angle with a flattened portion in area of air injection where the ramp becomes the bottom of the air injection duct.

Main Body

The main body is cylindrical to provide for ease of fabrication and satisfactory performance. Body diameter is somewhat flexible. If envelope restrictions require minimum size, the smallest diameter will be made up of air outlet diameter "C", air injection width "D", and two-phase inlet width "B" as shown in Figure 4.

One method of proportioning successful separators to a given flow rate is through equivalent centrifugal force. With unit weight of water being the same in all cases and the assumption that the water becomes a thin film on the separator wall, the predominant factor in the centrifugal force becomes $(\frac{V^2}{R})$. Through a series of $\pm$ one-g and zero-g tests (Ref. 1), the $(\frac{V^2}{R})$ for successful separator ranges from 1360 to 6265 m/sec^2 (1.61×10^7 to 7.4×10^7 ft/min^2). With a given radius or velocity, the magnitude of the other can be determined. This value is to be used as a rule-of-thumb only, as long as other separator design criteria are met.

The body length (dimension "E" on Fig. 4) has little effect on separator operation. A length of 4-1/2 to 6-1/2 times the height of inlet (dimension "A") has been most common in previous applications.

Air Injection Inlet

One of the major design improvements previously made by Martin Marietta for improved separator efficiency is that of injecting air (at a velocity and pressure greater than the two-phase inlet condition) between the air outlet tube and the deflector tube. This air flow prevents water film from creeping into the air outlet duct, which was a predominant shortcoming in earlier separators. Tests have shown that an air injection with a velocity 40-45% higher than the two-phase inlet or 20.3 m/sec (4000 fpm) (whichever is greater had excellent results. Likewise, the air injection flow rate should be 15-20% of two-phase inlet flow. The space between the deflector tube and air outlet duct should be sized to obtain the desired velocity (dimension "D" in Fig. 4) but not less than 9.5 mm (3/8-in.). The total available pressure of the air injection is to be greater than that of the two-phase inlet by 5.08 to 25.4 cm (2 to 10 inches) of water.

Higher flow rates of the air injection add to total system power requirements and is not recommended. Tests have verified that the recommended flow rates and velocity eliminate film creep.

Air Outlet

The air velocity in the outlet duct should be in the range of 3.45 to 6.90 m/sec (680 to 1360 fpm). This velocity range is below that which can drag water droplets along the interior surface of the outlet duct. The larger the outlet diameter, the lower the pressure loss, but the diameter should not be so large that the corresponding turbulent core is near the outer wall of the separator. Straightener vanes are required to eliminate the vortex pattern in the outlet tube thereby avoiding water re-entrainment and lowering the pressure drop. It has been empirically determined that the outlet should extend 1 to 1-1/2 times the height of the two-phase inlet beyond the deflection tube (dimension "F" in Fig. 4). To help prevent film creep, the inside edge of the air outlet tube should be chamfered.

Deflector

To help prevent water from the two-phase inlet to come in contact with the air outlet tube, a deflector tube is installed. The tube is concentrically located between the two-phase inlet and the air outlet tube and extends below the two-phase entrance, but above the air outlet to prevent drops which were spun off the deflector lip from being carried out the air outlet by secondary air eddy currents. Quantitatively, the deflector extends from top of separator into body of separator for a length (dimension "G" in Fig. 4) equal to 2 to 2-1/2 times the height of the two-phase inlet, dimension "A". The diameter of the deflector tube is to be made tangent to the inner wall of the two-phase inlet.

Conical Section and Vanes

At entrance to the sump the conical section should be an 80 deg cone (angle H in Fig. 4) and continue to a smooth transition at the separator body. Tests have shown that a smaller angle results in too high velocities at the sump entrance and the violent action results in water droplet re-entrainment. It has also been found that a larger angle lowers velocities to the point where there is insufficient driving force to move water into the sump.

To aid in driving water into the sump, vanes should be added to the conical section to impart an axial force to the spiraling water in that region. The vanes should make a gradual transition from radial to an axial direction. The vanes should start above the vortex breaker plate and have a surface height of 6.35 to 9.5 mm (1/4 to 3/8 inch).

Vortex Breaker Plate

A disc is placed just above the apex of the cone to break up the vortex action of the separator and provide a more tranquil area for water collection. Location of the vortex breaker plate is critical in that too low a position will not prevent liquid re-entrainment from the vortex action, and too high a position limits the driving force that moves the liquid into the sump. Tests have shown that in annular gap (dimension "I" of Fig. 4) of 12.7 to 17.46 mm (1/2 to 11/16 inch) is the best compromise for flow area around the vortex breaker plate. Also, the recommended height above the sump (dimension "J" in Fig. 4) is in the range of 19 to 31.75 mm (3/4 to 1-1/4 inches). The vortex breaker plate can be conveniently supported by the spiral vanes, thereby eliminating flow interference with support structure. To help prevent water from creeping from bottom to top of the vortex breaker plate, the edge of the disc should be sharp.

Water Outlet and Sump

The water outlet is the lowest part of the separator. The water should be pulled from the periphery of the sump if the sump diameter (dimension "K" in Fig. 4) is greater than 38.1 mm (1.5 inches) and pulled from the center if diameter is less. Diameter and length of the sump are largely dependent on water flow rate and should be tested for specific system requirements. Generally, a sump that is too large may cause turbulence in the sump regiòn and a sump too small in diameter may have cavitation problems due to surface tension.

SUMMARY OF VORTEX LIQUID/GAS SEPARATOR DESIGN GUIDES

1. Two-Phase Inlet
   - Tangential configuration
   - Rectangular shaped inlet with height-to-width ratio of approximately 2.0
   - Inlet velocity 13.21 to 28.2 m/sec (2600 to 5550 fpm).
2. Spiral Ramp at Inlet
   - Starts at top of tangential inlet
   - One 360 deg revolution with a pitch equal to height of two-phase inlet
   - Ramp width is defined as distance from outer separator wall to deflector tube.
3. Main Body
   - Minimum diameter is a buildup of air outlet diameter, air injection annulus, two-phase inlet annulus
   - Optimum diameter may be proportioned to $(\frac{V^2}{R})$ in the range of 1360 to 6265 m/sec^2 (1.61×10^7 to 7.4×10^7 ft/min^2)
   - Increasing diameter lowers pressure loss through separator
   - Wall velocity must be greater than 13.21 m/sec (2600 fpm)
   - Increasing diameter lowers wall velocity by 0.3% per 1% diameter increase
   - Body length should be 4-1/2 to 6-1/2 times the height dimension of the two-phase inlet.
4. Air Injection
   - Velocity to be 40-45% greater than two-phase inlet velocity or 20.3 m/sec (4000 fpm), whichever is greater
   - Flow rate to be 15-20% of two-phase inlet flow
   - Width of air injection inlet to be greater than 9.5 mm (3/8 inch)
   - Air injection pressure to be greater than two-phase inlet pressure by 3.72 to 18.64 mmHg (2 to 10 inches of water).

5. Air Outlet

- Velocity to be in the 3.45 to 6.9 m/sec (680 to 1360 fpm) range
- Larger diameter, lower pressure loss
- Straightener vanes to be added to eliminate vortex motion in outlet and reduce pressure loss
- Air outlet tube in separator should extend past deflector tube by 1 to 1-1/2 times the height of the two-phase inlet
- Inside edge of tube to be chamfered.

6. Deflector Tube

- Tube to extend from top of separator into the body for a length equal to 2 to 2-1/2 times the height of the two-phase inlet
- The bottom edge of the deflector tube to be chamfered on the inside
- The diameter is to be tangent with the inner wall of the two-phase inlet.

7. Conical Section and Vanes

- Cone angle to be 80 deg at sump inlet with a gradual smooth transition to separator body
- Vanes to start above vortex breaker plate and have a gradual transition from radial to axial orientation
- Vane height should be 6.35 to 9.5 mm (1/4 to 3/8 inch).

8. Vortex Breaker Plate

- Peripheral clearance to be 12.7 to 17.46 mm (1/2 to 11/16 inch
- Height above sump to be 19 to 31.75 mm (3/4 to 1-1/4 inches)
- Vortex breaker plate to be supported by vanes
- Edge to be sharp.

9. Water Outlet and Sump

- Water to be pulled from periphery of sump when diameter is greater than 38.1 mm (1.5 inches) and pulled from the center if diameter is less
- Length of sump to be sized to specific system requirements.

REFINEMENTS TO SSP SHOWER LGS

The original separator for the Zero-G Whole-Body Shower was sized to operate with flow requirements of the SSP shower. It was also designed to be as compact as possible to keep overall envelope size at a minimum. The two major refinements to the present design would be in the area of reducing the two-phase velocity through the separator (by utilizing a larger inlet area or increasing body diameter or both) and moving the separated water farther away from the turbulent center core of the separator (by enlarging body of separator). The objective behind the velocity reduction is to lower the energy imparted to the two-phase flow and hence its sudsing capacity. The following table (Table 3) lists the parameters in separator design and the corresponding values for the present separator and recommended values for the refined separator. Values for both separators are based on an inlet two-phase flow of .01321 m^3/sec (28 cfm).

The following discusses differences between the present and refined separator data in Table 3.

Item 1 - Lowering inlet velocity lowers imparted energy to two-phase fluid which lowers sudsing capacity.

Item 2 - The same diameter for the refined LGS permits separator-to-shower interface to remain unchanged.

Item 3 - $(\frac{V^2}{R})$ term for proposed separator falls within the acceptable range.

Item 4 - The same body length for the refined LGS permits separator-to-shower interface to remain unchanged.

Item 5 - The air injection velocity will be increased from 18.9-25.4 m/sec (3730-5000 fpm) to maintain the deflector cylinder free of droplets.

Item 6 - Air outlet tube is smaller in diameter and therefore the distance from the turbulent center core to the water film on walls is increased. Also the separator-to-shower interface remains unchanged.

Item 7 - The 80 deg cone angle has been found to be optimum and is recommended for the proposed separator.

Table 3 Separator Parameters

ITEM	Variable	SSP Shower LGS	Refined LGS
1	Two Phase Inlet Velocity	18.3 m/sec (3600 fpm)	14.7 m/sec (2900 fpm)
2	Body Diameter	15.875 cm (6.25 in.)	15.875 cm (6.25 in.)
3	Value for $(\frac{V^2}{R})$ term	2074 m/sec^2 (2.45×10^7 ft/min^2)	1372 m/sec^2 (1.62×10^7 ft/min^2)
4	Body Length	3.74 cm (9.5 in.)	3.74 cm (9.5 in.)
5	Air Injection Velocity	18.9 m/sec (3730 fpm)	25.4 m/sec (5000 fpm)
6	Air Outlet Velocity	2.9 m/sec (575 fpm)	3.4 m/sec (672 fpm)
7	Cone Angle	80 deg	80 deg
8	Vortex Breaker Plate Peripheral Clearance	16 mm (.63 in.)	17.5 mm (.69 in.)
9	Vortex Breaker Plate Height from Sump Opening	23.8 mm (.94 in.)	31.75 mm (1.25 in.)
10	Diameter of Sump	4.76 cm (1.875 in.)	4.76 cm (1.875 in.)
11	Sump Length	15.57 cm (6.13 in.)	25.73 cm (10.13 in.)

Item 8 - The proposed separator has a slight increase in the peripheral clearance of the vortex breaker plate to permit more rapid water passage into the sump.

Item 9 - The height of the vortex breaker plate from the sump opening is increased to reduce the turbulence at the apex of the separator and thereby reduce sudsing in this region.

Item 10 - The sump diameter on the present separator is satisfactory for certain cleansers and may be used on the refined separator.

Item 11 - The sump length may also be increased [up to 30.48 cm (12 in.)] to prevent the pushing of suds above the vortex greaker plate when the water is at the high point. Additional time is given to suds to transform back to the liquid state to trigger level sensors properly. In this case a wider selection of soaps is possible.

SYSTEM ANALYSIS

Sudsing Control Methods

From a system viewpoint, there appear three methods to limit suds generation in the Space Station Prototype (SSP) shower system. These are (1) reduce agitation throughout system (including separator), (2) utilize low sudsing soap, and (3) utilize defoaming agents in the system and/or separator.

Reduction of Agitation

All hoses and ducting from two-phase pickup to separator should be smooth bore with a minimum of bends. The bends that cannot be eliminated should be gradual with as large radius of curvature as possible. Water pickup and removal should be steady to eliminate water surging through the pickup hose and in the separator.

Agitation can be reduced if the two-phase velocity is reduced. The higher the velocity the higher the imparted energy in the fluid and the higher the potential of suds generation. The velocity should be as low as possible and still provide satisfactory two-phase fluid movement in the vacuum pickup hose and in the separator.

In the separator, the water phase should be displaced as far as possible from the turbulent center core. This can be accomplished by incorporating the largest possible separator body (depending on envelope restrictions and centrifugal force developed) relative to outlet duct diameter.

Low Sudsing Soap

A survey of applicable soaps for zero gravity showers was conducted with an emphasis on sudsing as much as feeling-of-cleanliness, skin irritation, and control of bacterial growth. The Neutrogena Rain Bath soap has been found to be one of the most undesirable soaps in respect to sudsing, although the other qualities are very attractive. Likewise, the Miranol Jem was found to be low sudsing, but left an objectionable odor as commented by several test subjects. The possibility of developing a low sudsing soap specifically for space applications may have some merit.

Defoaming Agents

The addition of a very small quantity of an anti-sudsing agent may be desirable. This agent may be solutions or granules of calcium, sodium, or potassium salt that are introduced in the two-phase fluid prior to separator entrance. One scheme which was considered is shown in Figure 5.

Another method to deter sudsing is to coat surfaces in contact with the soapy water with a silicone film (a known antisudsing agent). These surfaces include the vacuum pickup hose, ducting, and separator interior walls. Also, mechanical means can be incorporated to break up the suds bubbles. These can take the form of needles placed in the air stream at the entrance to the air outlet.

Another method of suds control is the use of alpha/beta ray emitters. These are available in small self-sustaining modules and are a means for upsetting the balance of the stabilized energy system of the bubbles.

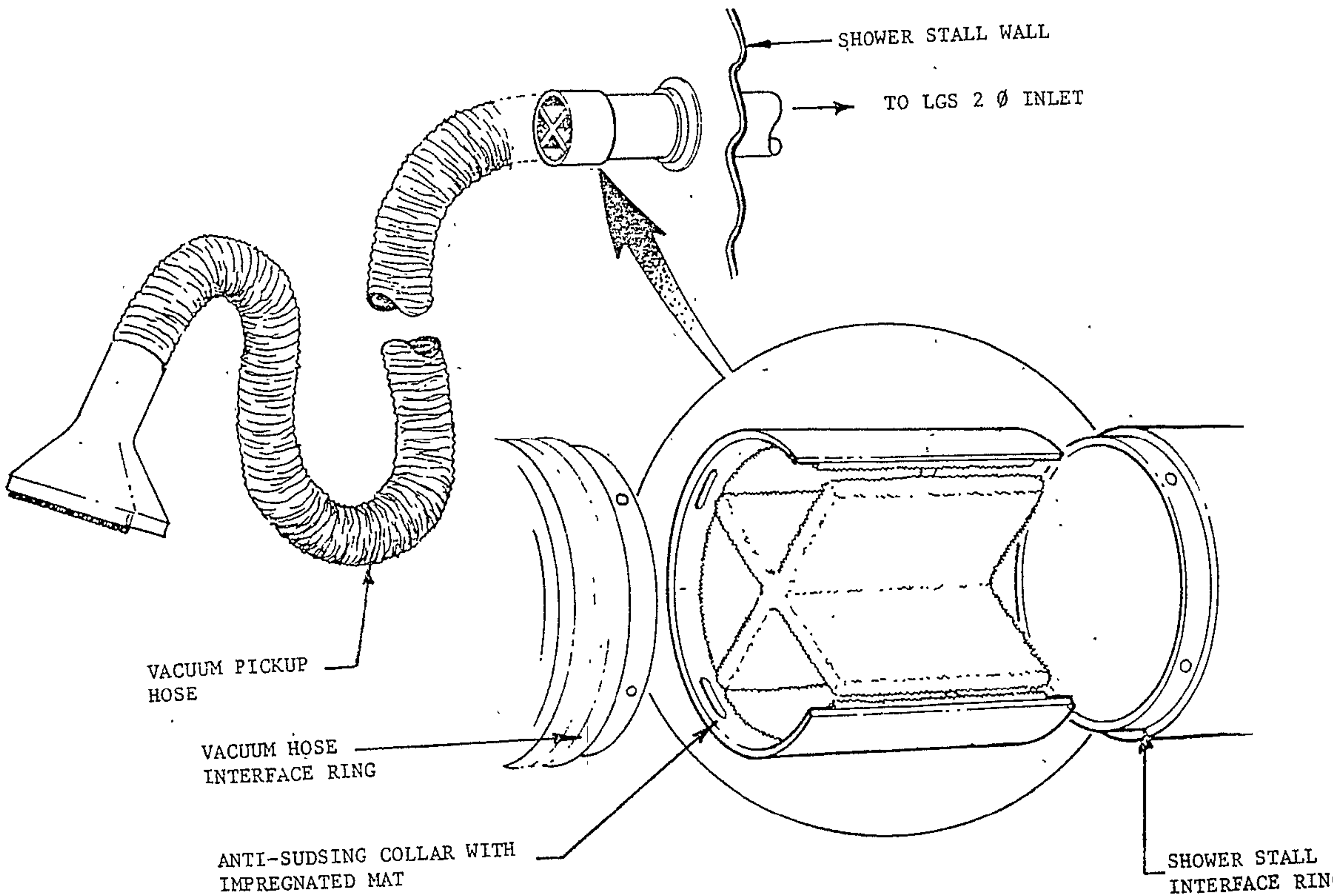


Figure 5 Impregnated Anti-Sudsing Collar

DEVELOPMENT TEST

Before proceeding with the final design and fabrication of the LGS (Task 2), a development test effort was initiated. It was understood that some of the following items are interrelated and the result of some tests would impact the course of related tests:

1. Using an existing test separator of 25.4 cm (10 inches) diameter and a soapy two-phase flow, the velocity at separator inlet was varied to determine effect of velocity on sudsing.
2. The same separator was used to determine degree of sudsing for different types of soaps and soap concentration.
3. The same separator established the effect on sudsing caused by pure (distilled) water.
4. The degree of suds reduction with a silicone and other films on interior surfaces was determined from the test separator.
5. Addition of needles was considered for test on proposed separator model.
6. Effect of alpha/beta emitter on breaking up soap bubbles was tested.
7. Model of proposed separator configuration was constructed and tested.

Figure 2 is a schematic definition of the development test configuration and its elements.

1. Velocity Effect

Using an existing test separator of 25.4 cm (10 inches) diameter and a soapy two-phase flow, the velocity at the separator inlet was varied to determine effect of velocity on sudsing. Tests 8 through 12 (Appendix A) were conducted with inlet velocity at the "choke" point ranging from 13.21 to 43.4 m/sec (2600 to 8550 fpm). Neutrogena Rainbath liquid soap was used as the "control" in view of its high sudsing characteristics. The soap-to-water ratio in all cases was 20 ml/3785 ml water, which is consistent with the ZGWBS specification.

Test results of the above show little if any effect created by these inlet velocity variations and no consistent pattern of change in suds generation was seen. Excessive buildup of suds was noted in each instance.

It should be pointed out, however, that when the vacuum pick-up line was bypassed, no buildup of suds was noted even at an inlet velocity of 43.4 m/sec (8550 fpm). This latter test pointed to the possibility that the vacuum pickup hose was a major contributor to the "excess sudsing" problem.

2. Suds Generation

The same separator as used in the foregoing test was used for determining the degree of separator sudsing for different types of soaps and soap concentrations. Comparison tests were conducted on Neutrogena, Phisohex, Miranol (C2M-SF Conc.), Ivory, Olive Leaf, and Irish Spring. Neutrogena was used as the control against which other soaps were compared. Both "steady state" and "slugging" flow were employed in this evaluation of the soaps (see test data sheets 1 through 3 and 16 through 18). The soap-to-water ratio for the liquid soaps was 20 ml/3785 ml water, which is consistent with the ZGWBS specification. Bar soap weight-to-water ratio was determined by actual shower measurements.

The conclusion reached as a result of these tests was that Neutrogena liquid soap was an extremely active sudser and under no circumstances, including steady state liquid flow, could it be considered for use in the ZGWBS. In every case tested, Neutrogena created suds to an undesirable level (an accumulation of suds above the vortex breaker plate being considered as undesirable). Even Phisohex which is considered to be a low sudser was found unsatisfactory in a continuous "slugging" pickup situation. Similarly, Miranol (C2M-SF) was unsatisfactory under these conditions.

At this point it was felt that a sufficient amount of visual evidence had been observed to suspect the vacuum pickup hose and transition pieces as major contributors to the generation of suds. To evaluate this possibility, several tests (Nos. 4, 11, and 32 thru 37) were conducted and it was found that by bypassing the vacuum pickup line, a significant reduction in suds formation was possible under "steady state" flow conditions.

A smooth bore glass tube was fabricated to simulate the vacuum pickup hose. By this means we could observe the two-phase flow conditions in the pickup tube and at the same time determine the effectiveness of the smooth bore glass tube as opposed to the ZGWBS flex hose (Test Nos. 19 thru 21, 40 thru 45). From these tests it was learned that even the smooth bore glass pickup tube was a significant contributor to suds generation. Furthermore, bypassing this tube resulted in a large reduction in the amount of suds generated. Hence, the vacuum pickup hose had been shown to be a major contributor to the excess suds problem.

3. Water Quality

The intent of test runs 13 through 15 was to evaluate the impact of using mineral-free (distilled) water in place of the Denver tap water. Neutrogena, Miranol C2M-SF, and Phisohex liquid soaps were tested. The soap-to-water ratio was 20 ml to 3785 ml water as in previous tests. Air flow was also the same. Test results showed a much more vigorous buildup of suds than with Denver water. Even though the Phisohex soap did not create a "carry-over" situation, mineral-free water was contraindicated.

A previous contract comparison of Denver water with the SSP specification for potable water showed the Denver water purity to be well above the SSP specification water. Therefore, it may be concluded that MMC testing with Denver water should give conservative test results. However, as indicated by the foregoing distilled water test results, careful consideration must be given to "excess sudsing" when the final water selection is made.

4. Defoaming/Anti-foaming Agents

Alternate approaches may be available to the management of the sudsing problem. The addition of a very small quantity of an anti-sudsing agent may be desirable. Another possibility is to coat the inside surfaces of the "containing" elements with known anti-sudsing agents such as silicone which is highly insoluble in water.

Discussions with leaders in the soap manufacturing field led to recommendations of various approaches that might lead to a reduction of "excess sudsing." These approaches included the following:

(a) silicone grease coatings;
(b) teflon lining;
(c) aluminum lining;
(d) "rubberized" silicone;
(e) chemical addition.

Tests 22 through 31 and 59 through 62 represent all the above approaches. Only partial successes were obtained, i.e., silicone coatings or chemical additions were only successful on the addition of "heavy doses." Such large dosage would be entirely unacceptable to the downstream water reclamation system. Approaches (b), (c), and (d) were totally ineffective.

5. Addition of Needles

During the course of discussions with the technical staff of a major soap manufacturer, it had been suggested that a dense pattern of sharp needles at the internal entrance to the separator air outlet might be beneficial in preventing suds carryover. As the result of numerous observations during the foregoing tests it was noted that the suds generated within the separator were extremely stable and generally of a very small diameter. Tests with even fine mesh screens did not prevent the passage of soap suds and sharp needles did not seem to burst bubbles but rather acted as passageways for the tiny bubbles to continue their flight.

These approaches to mechanically break down the suds were not pursued beyond this point in view of the above negative results and the high pressure drop nature of such mechanical devices.

6. Alpha/Beta Emitters

Another method suggested for upsetting the energy balance of bubbles within soap suds was the application of either alpha or beta rays. It was postulated that such an application might burst a sufficient number of bubbles to start a "chain reaction" in the soap suds.

Suds were generated in a 400 ml (24.4 in.^{3}) beaker filled with a soapy solution and were then exposed to alpha radiation given off by polonium sources.

The sources were Static Master 500, Model #3C500 and Model #1C200 (both by Nuclear Products Co., El Monte, California).

The emitters were held at a point immediately above the suds which had been generated in the 400 ml beaker. No visible effect whatsoever was in evidence. The suds were quite stable and remained in this condition when exposed to the emitter.

7. Breadboard Model

A breadboard model which incorporates the recommended internal configuration changes was fabricated and tested in order to evaluate its performance before proceeding with fabrication of the deliverable hardware. The material for the model was a thin sheet plastic (0.030 CAB) and was joined by a "CA" bonding cement (see Figs. 6 and 7).

Eight different soaps, Olive Leaf, Neutrogena, Irish Spring, Lux, Camay, Jergens, Ivory, and Safeguard, were used in the performance test of the breadboard model. In all, 19 tests (46 through 64) were conducted to permit a preliminary selection of soaps. Of these soaps, four were tentatively selected for further evaluation and performance testing at NASA-JSC. The soaps were Olive Leaf, Ivory, Camay, and Safeguard. Neutrogena was again identified as the worst sudser while Olive Leaf provided the least sudsing problem.

It was also determined in this series of tests that without man in the loop the separator evaluation is very conservative. A direct comparison (Tests 54 and 55) showed that when the two-phase fluid contained the wastewater from an actual shower, there was no suds buildup or carryover. It was concluded that the reason for the significant difference is due to the addition of body oils and salts to the wastewater. This test was confirmed, with a different soap, in Tests 57 and 58.

On the basis of the promising results of the foregoing tests, fabrication of the deliverable article was initiated.

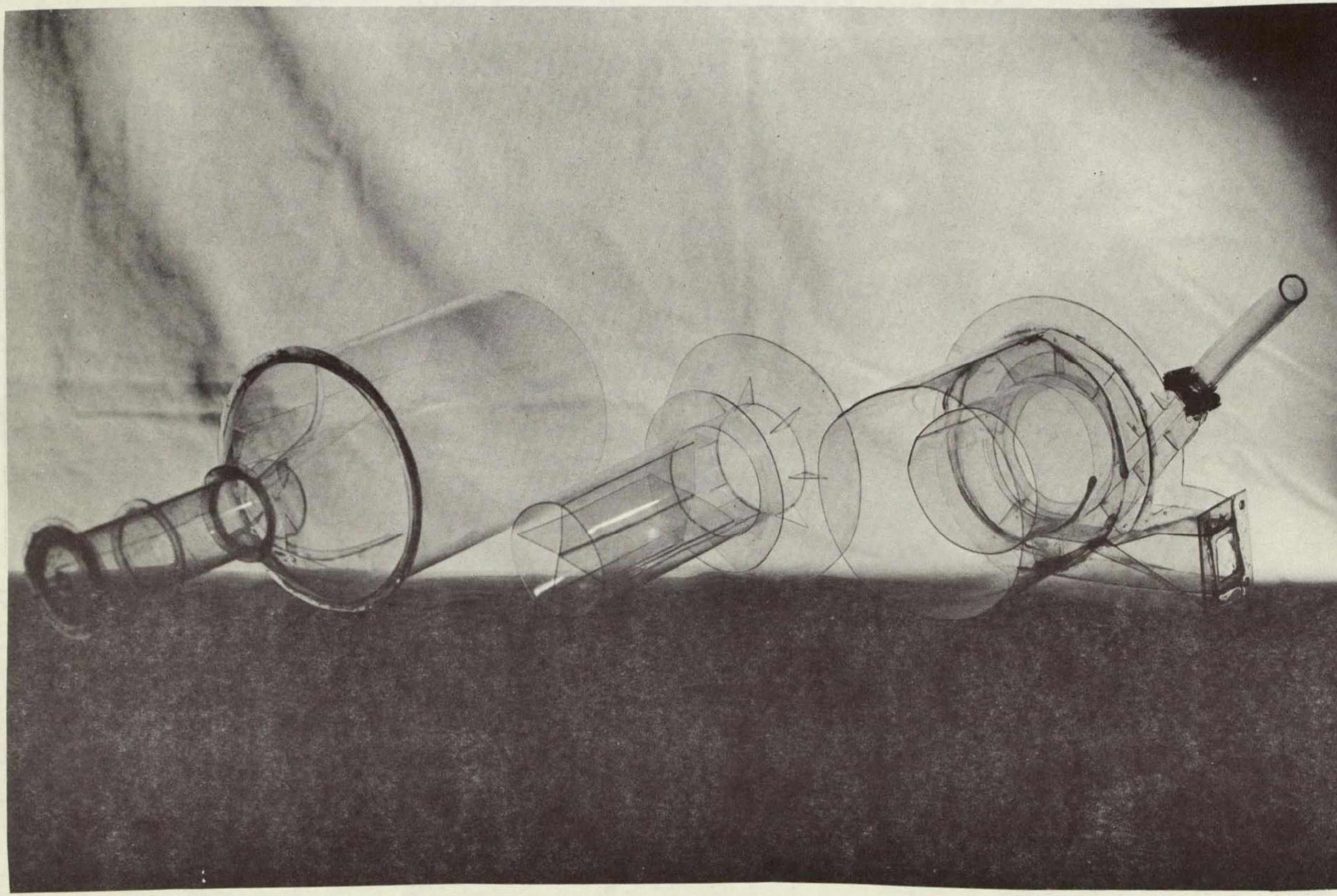


Figure 6 Breadboard Model (before bonding)

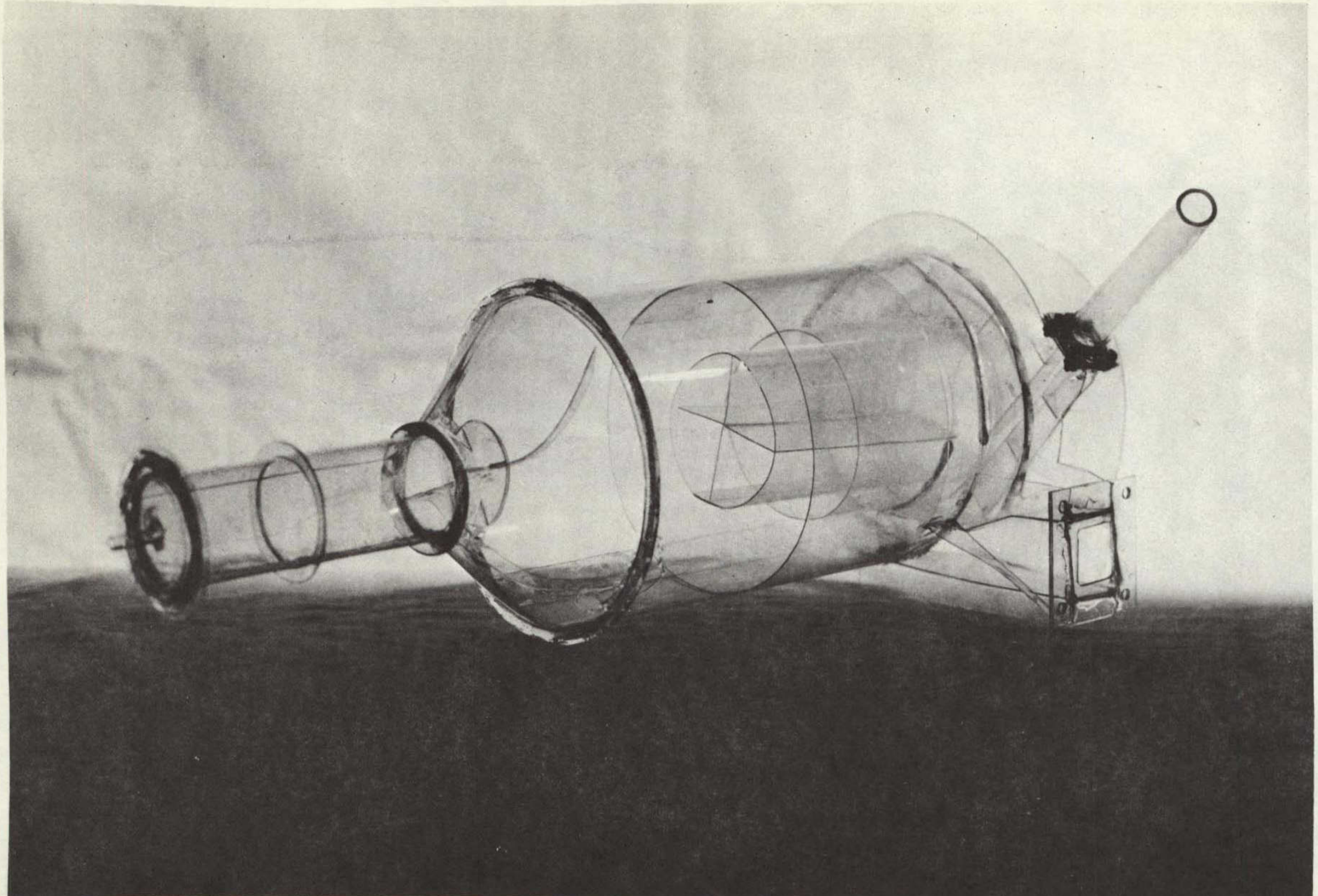


Figure 7 Breadboard Model (after bonding)

TASK 2 - DESIGN
LIQUID/GAS SEPARATOR DESIGN REVISIONS

As part of Task 1, the vortex LGS was analyzed in detail to determine the refinements to be applied to the original design in order to aid in the prevention of excess suds and liquid carryover. On the basis of these findings, separator dimensional changes were studied to give the desired changes in flow velocity and internal configuration.

In all, five basic internal dimensional changes were incorporated to optimize the operation of the LGS. Furthermore, a deeper sump configuration was developed to provide for a longer dwell time of the suds in the sump cavity. The latter permits a more effective breakdown of the suds into liquid before being pumped out of the sump.

Changes which were incorporated at this time and the velocities associat with them to achieve optimum flow are as follows (reference Fig. 4):

Table 4

Dimensional Designation	Change	Remarks
A	None	Maintain interface.
B	Increase to 25.4 mm (1.00 in.)	Decrease velocity to 14.7 m/sec (2900 fpm) to reduce ($\frac{V^2}{R}$) to low side of optimum range.
C	Reduce to 7.62 cm (3.00 in.) dia.	Reduce the diameter of turbulent core, velocity = 3.4 m/sec (672 fpm)
D	Reduce to 9.5 mm (3/8 in.)	Increase injection velocity to 25.4 m/sec (5000 fpm) to high end of optimum scale
E	None	Maintain interface.
F	Reduce by 1.5 mm (0.06 in.)	To accommodate two-phase inlet change (no velocity impact).
G	Increase by 1.5 mm (0.06 in.)	To accommodate two-phase inlet change (no velocity impact).
H	None	80 deg satisfactory in previous testing.
I	17.5 mm (0.69 in.)	Allow more clearance for water passage.
J	31.7 mm (1.25 in.)	Allow more clearance for water passage.
K	None	Satisfactory in previous testing.

All the above changes are in fulfillment of the recommendations and findings of Task 1. They are incorporated on the original separator drawings (Martin Marietta Corporation Drawing #89900000897, Sheets 1 through 6, Figures 8 through 13).

NOTES:

1. CONSECUTIVE DASH NUMBERS ARE USED ON THIS DRAWING - DASH NUMBERS 009, 010, 019, 020, 024 ARE ASSEMBLY NUMBERS - ALL OTHER DASH NUMBERS ARE DETAIL NUMBERS. ALL ITEMS ARE AS SHOWN
2. BURR ALL CORNERS AND BREAK ALL SHARP EDGES UNLESS OTHERWISE NOTED
3. MACHINED SURFACES MUST HAVE A GOOD ENOUGH FINISH TO BE SEEN THROUGH
4. ALL JOINTS EXCEPT FLANGE CONNECTIONS BETWEEN 010, 019 & 020 TO BE BONDED WITH TETRAHYDROFURAN (THF) OR OTHER SUITABLE AGENT
5. COMPLETED SEPARATOR ASSEMBLY (009) TO BE BUBBLE TIGHT AND TESTED BY SUBMERSION IN WATER WHILE PRESSURIZED TO 4 PSIG FOR 3 MINUTES
6. CENTERLINES OF ASSEMBLED PARTS TO BE CONCENTRIC WITHIN .02"

1 7. SHEET 1 - ITEMS 005, 011, AND 013 CAN BE MADE FROM THE TUBING SIZES CALLED OUT, OR FORMED FROM 1/8" THICK SHEET.

2 8. SHEET 2 - ITEMS ON 010 TO BE SHIPPED LOOSE AND UNASSEMBLED.

3 9. SHEETS 4 & 5 - FLAGGED DIMENSIONS TO BE SNUG SLIP FITS UPON ASSEMBLY

5 11. SHEET 1 - MATERIAL SPECIFICATION PER MFR GENERAL ELECTRIC

12. REGARDLESS OF TOLERANCES, ALL MATING PARTS SHALL FIT TOGETHER WITH A SNUG SLIP-FIT, TO A LOOSE SLIP FIT

6 CLEAR ACRYLIC MATERIAL TO BE AN ALLOWABLE SUBSTITUTE FOR LEXAN

7 SELECTION OF SUMP ASSY WILL BE MADE PRIOR TO SEPARATOR INSTALLATION (BOTH -010 AND -024 ASSEMBLYS ARE TO BE FABRICATED)

8 ALLOWABLE MATERIAL SUBSTITUTE IS SILICONE S 455 70

Rev	Description	Date	Approved
	INITIAL RELEASE		
A	ADDED EPS 45007		
B	ADDED FLAGNOTES 6, 7, AND 8; ADDED -031 DETAIL AND -024 ASSY		

Qty	Part No.	Nomenclature	Stock Size	Material	Notes
1	-031	BAR	4in DIA x 10 LG	9030 112 LEXAN	3 6
	EPS 45037	ENG PROC SPEC	IDENTIFICATION AND MARKING OF DETAIL PARTS AND ASSEMBLIES		
1	89900000941-195	"O" RING	PARKER 2-260	SILICONE S604-7	8
1	89900000941-193	"O" RING	PARKER 2-261	SILICONE S604-7	8
1	89900000941-191	"O" RING	PARKER 2-273	SILICONE S604-7	8
1	89900000761-213	V BAND COUPLING	[illegible]	STAINLESS STEEL	
16	AN960C10L	WASHER	[illegible]	STAINLESS STEEL	
16	MS21042L3	HEX LOCKNUT	10-32	STAINLESS STEEL	
8	NAS1351C-3-20	ALLEN HD CAP SCREW	10-32 x 1 1/4 LG	STAINLESS STEEL	
7	-028	PLATE	[illegible]	9030-112 LEXAN	6 5
1	-027	PLATE	[illegible]		
1	-026	PLATE	[illegible]		
1	-025	PLATE	[illegible]		
1	-024	PLATE	[illegible]		
1	-023	PLATE	[illegible]		
1	-022	PLATE	[illegible]		
4	-021	PLATE	[illegible]	9030-112 LEXAN	6 5
1	-018	SHEET	[illegible]	SILICONE [illegible]	MS 4068
1	-017	PLATE	[illegible]	9030-112 LEXAN	5 6
1	-016	SHEET	[illegible]	SILICONE [illegible]	MS 4068
1	-015	PLATE	[illegible]	9030-112 LEXAN	5 6
1	-014	PLATE	[illegible]		
1	-013	TUBE	[illegible]		
1	-012	PLATE	[illegible]		
1	-011	TUBE	[illegible]		
1	-008	PLATE	[illegible]		
4	-007	PLATE	[illegible]		
1	-006	PLATE	[illegible]		
1	-005	TUBE	[illegible]		
1	-004	PLATE	[illegible]		
1	-003	BAR	[illegible]		
1	-002	BAR	[illegible]		
1	-001	BAR	[illegible]	9030-112 LEXAN	6 5
1	-024	SUMP ASSEMBLY	7		
1	-020	UPPER BODY ASSY			
1	-019	LOWER BODY ASSY			
1	-010	SUMP ASSEMBLY	7		
	-009	LIQUID GAS SEPARATOR ASSY			

LIST OF MATERIAL

89900000849

M. D. TEVERAAUGH

VORTEX LIQUID-GAS SEPARATOR ASSEMBLY

E 04236 89900000897

ORIGINAL PAGE IS OF POOR QUALITY

Figure 8

29

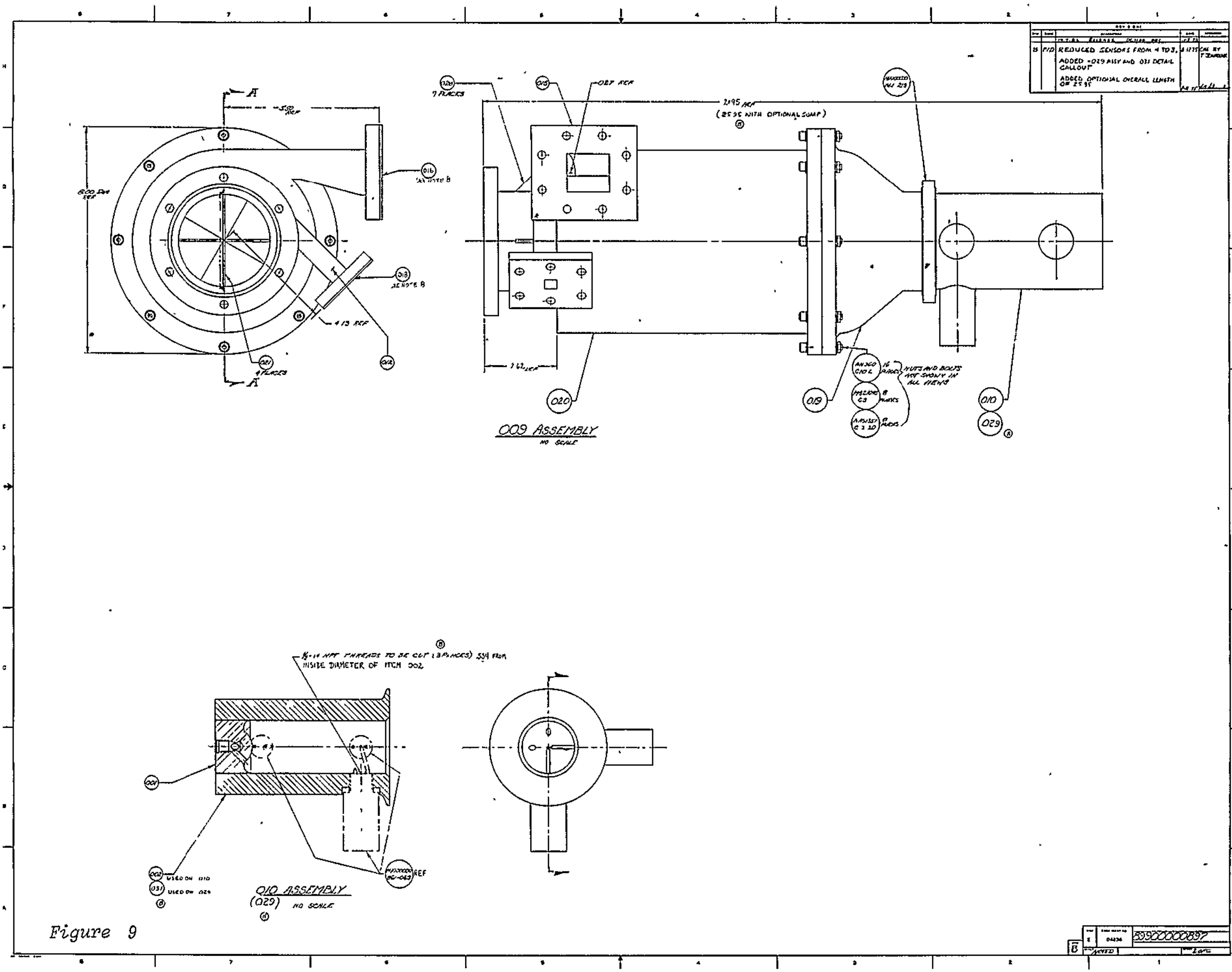
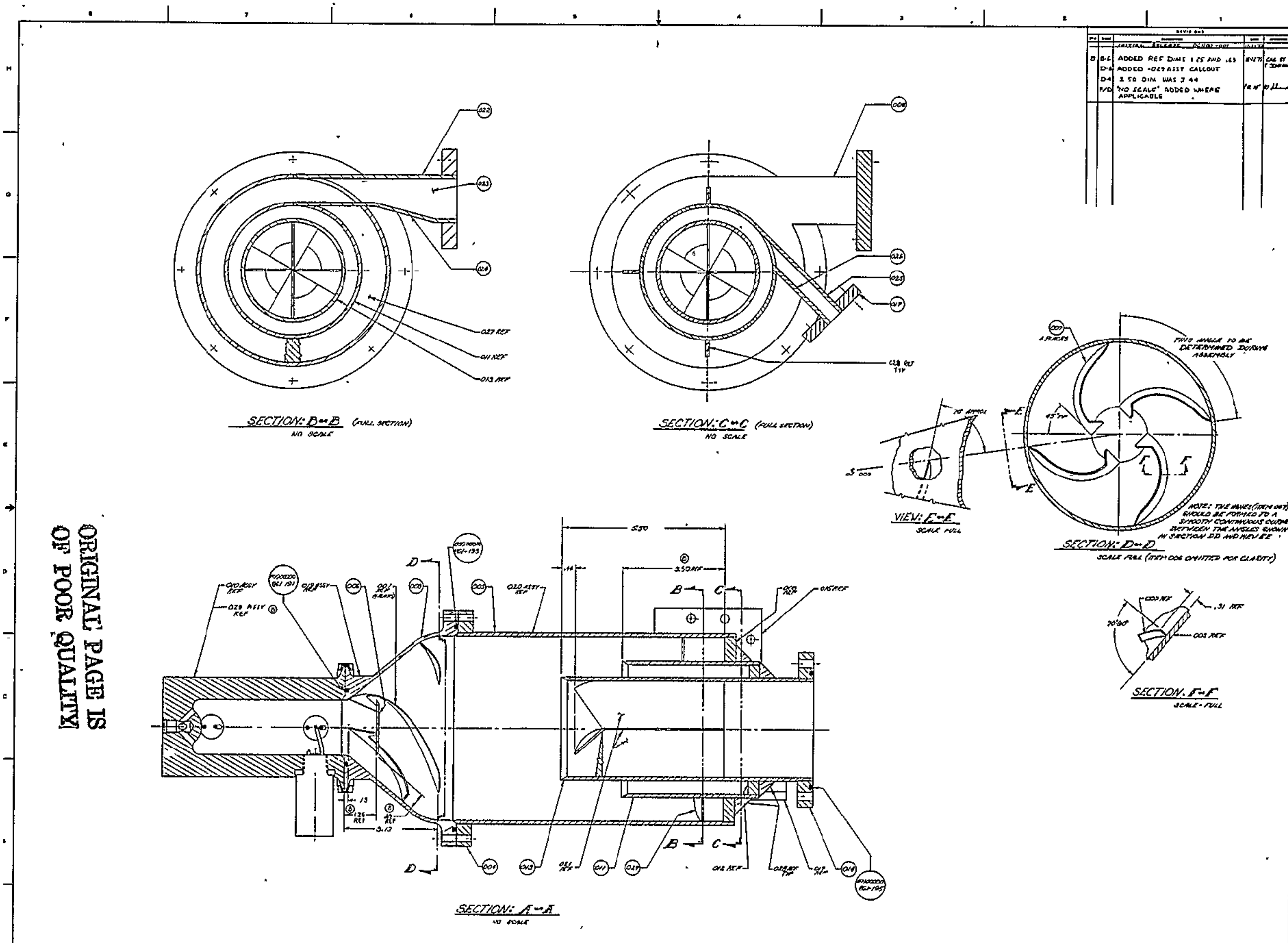
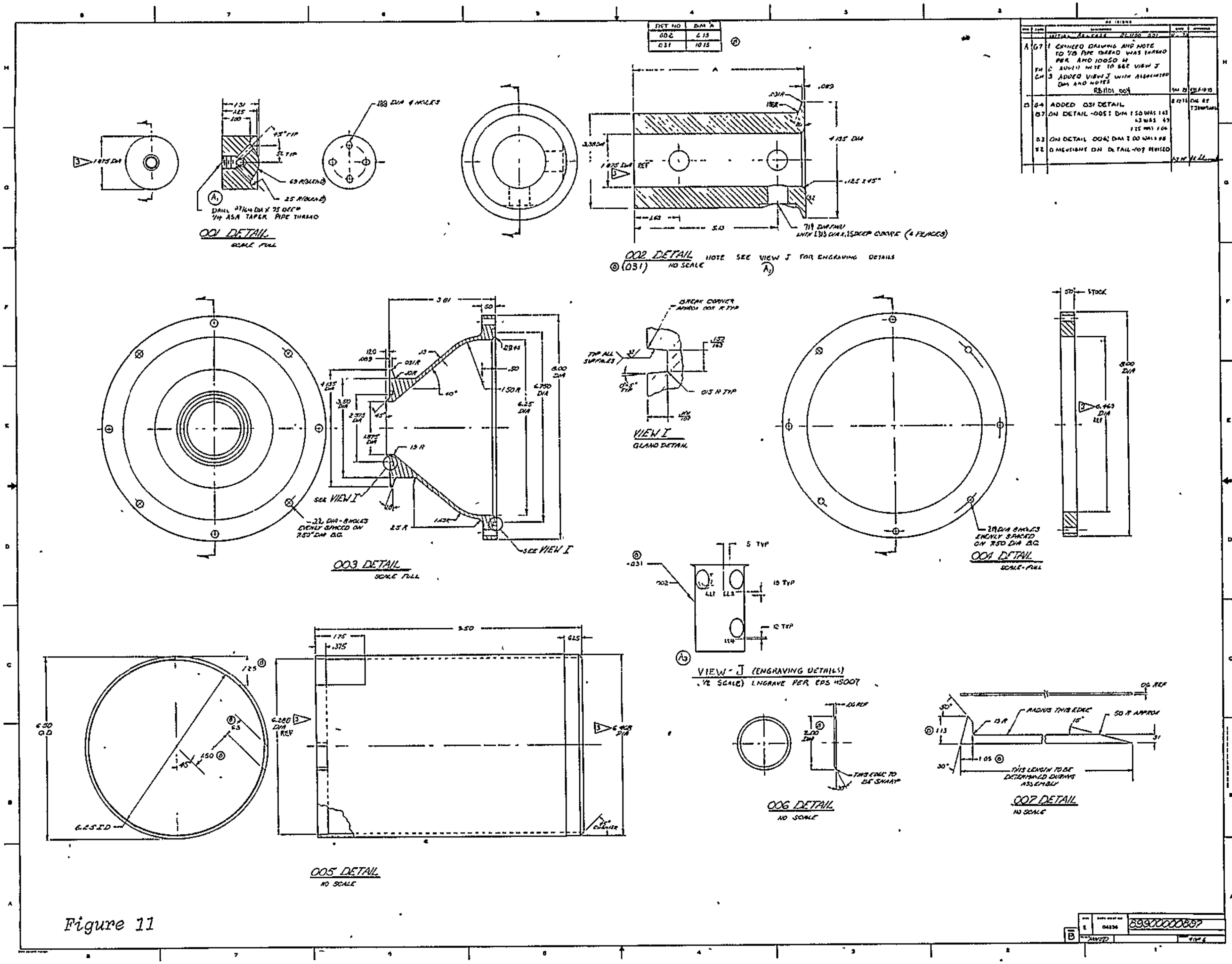

REDUCED SENSORS FROM 4 TO 3
ADDED -029 ASSY AND 031 DETAIL CALLOUT
ADDED OPTIONAL OVERALL LENGTH OF 25.95
7 PLACES
027 REF
2195 REF
(25.95 WITH OPTIONAL SUMP)
NUTS AND BOLTS NOT SHOWN IN ALL VIEWS
009 ASSEMBLY
NO SCALE
INSIDE DIAMETER OF ITEM 002
USED ON 010
USED ON 029
010 ASSEMBLY
(029)
NO SCALE
REF
59900000897

Figure 9



SECTION: B-B (FULL SECTION)
NO SCALE
SECTION: C-C (FULL SECTION)
NO SCALE
VIEW: E-E
SCALE FULL
SECTION: D-D
SCALE FULL (ITEM 006 OMITTED FOR CLARITY)
SECTION: F-F
SCALE-FULL
SECTION: A-A
NO SCALE
39900000897

Figure 10



001 DETAIL
SCALE FULL
002 DETAIL
NO SCALE
NOTE SEE VIEW J FOR ENGRAVING DETAILS
003 DETAIL
SCALE FULL
VIEW I
GLAND DETAIL
004 DETAIL
SCALE FULL
VIEW - J (ENGRAVING DETAILS)
005 DETAIL
NO SCALE
006 DETAIL
NO SCALE
007 DETAIL
NO SCALE
ADDED 031 DETAIL
89900000897

Figure 11

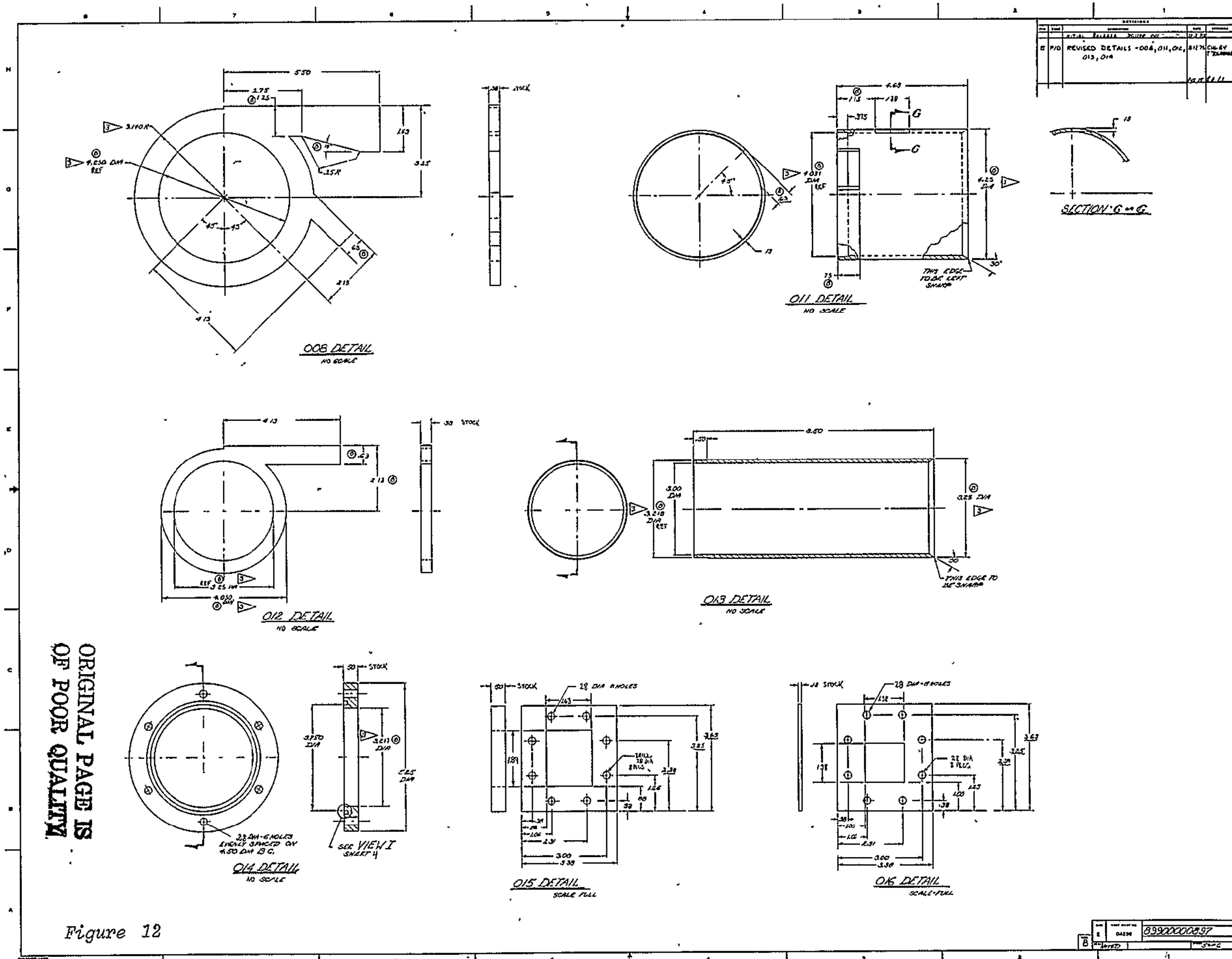

REVISED DETAILS -008, 011, 012, 013, 014
008 DETAIL
NO SCALE
011 DETAIL
NO SCALE
THIS EDGE TO BE LEFT SHARP
SECTION G-G
012 DETAIL
NO SCALE
013 DETAIL
NO SCALE
THIS EDGE TO BE SHARP
014 DETAIL
NO SCALE
.28 DIA-6 HOLES EVENLY SPACED ON 4.50 DIA B.C.
SEE VIEW I SHEET 4
015 DETAIL
SCALE FULL
.28 DIA-8 HOLES
016 DETAIL
SCALE-FULL
.28 DIA-8 HOLES

Figure 12

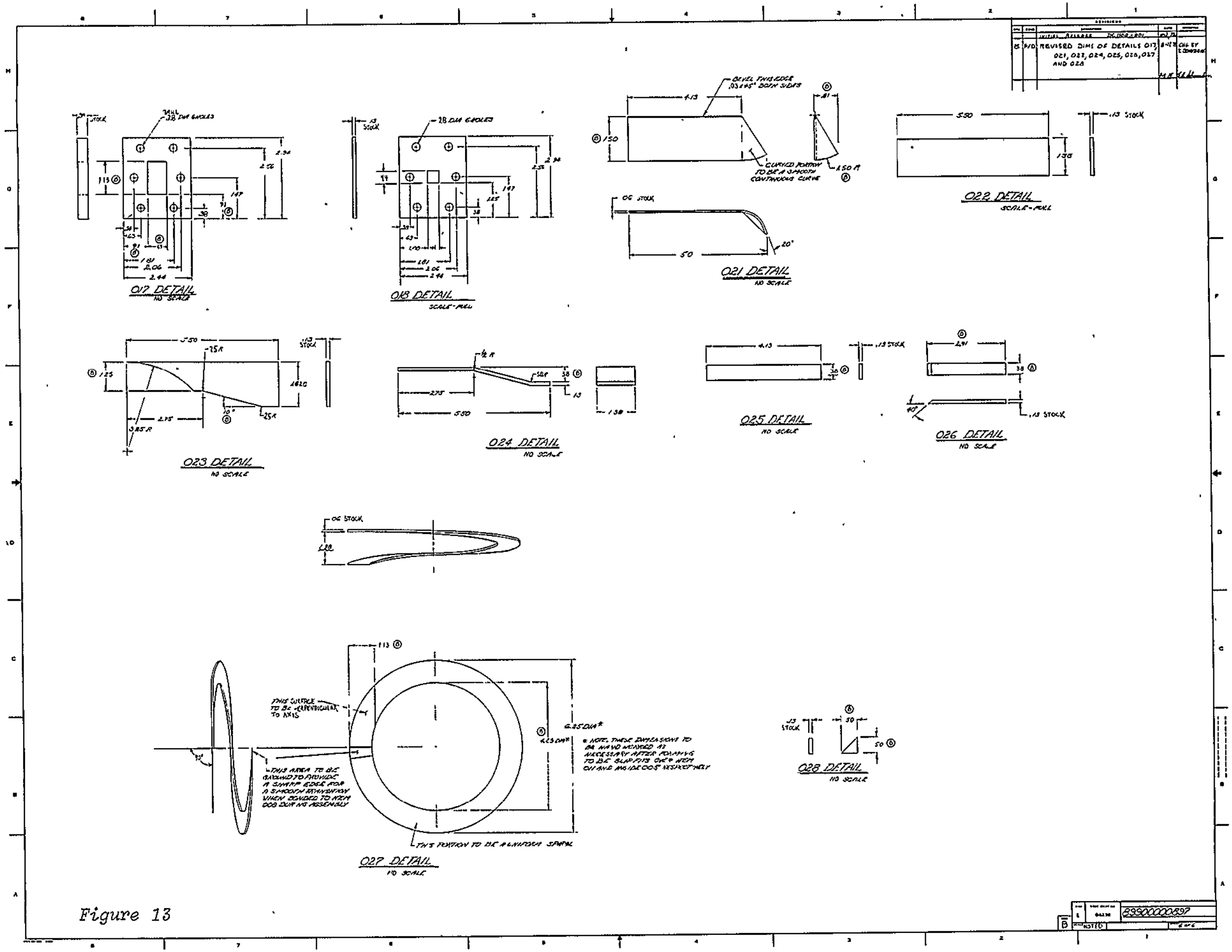

REVISED DIMS OF DETAILS 017, 021, 022, 024, 025, 026, 027 AND 028
017 DETAIL
NO SCALE
.38 DIA 6 HOLES
018 DETAIL
SCALE - FULL
.28 DIA 6 HOLES
021 DETAIL
NO SCALE
BEVEL THIS EDGE .03 x 45° BOTH SIDES
CURVED PORTION TO BE A SMOOTH CONTINUOUS CURVE
.06 STOCK
022 DETAIL
SCALE - FULL
.13 STOCK
023 DETAIL
NO SCALE
024 DETAIL
NO SCALE
025 DETAIL
NO SCALE
026 DETAIL
NO SCALE
.06 STOCK
THIS SURFACE TO BE PERPENDICULAR TO AXIS
THIS AREA TO BE GROUND TO PROVIDE A SHARP EDGE FOR A SMOOTH TRANSITION WHEN BONDED TO ITEM 003 DURING ASSEMBLY
6.25 DIA*
4.25 DIA*
* NOTE: THESE DIMENSIONS TO BE HAND WORKED AS NECESSARY AFTER FORMING TO BE SLIP FITS OVER ITEM 011 AND INSIDE 005 RESPECTIVELY
THIS PORTION TO BE A UNIFORM SPIRAL
027 DETAIL
NO SCALE
028 DETAIL
NO SCALE
89900000897

Figure 13

TASK 3 - FABRICATION
LIQUID/GAS SEPARATOR FABRICATION AND FUNCTIONAL CHECKOUT

The deliverable liquid gas separator unit was fabricated in our Composites Laboratory which is utilized for the development of all types of plastic laminates, shapes, and pressure vessels. Most of the detail parts were made by lathe operations, polishing, and hand-fitting since only a single end item was required. No particularly difficult problems arose during the course of fabrication and assembly because only current state of the art was involved.

A satisfactory pressure leak test at 52.2 mmHg (28 in. of water) pressure (1 psi) was conducted to check for leakage. At this time, a verification of interface compatibility was made by checking the unit against the production drawings. The unit was then delivered to the Life Sciences Lab for a functional test as part of the two-phase flow system. The same test hardware as had been used for the development test was again employed. In this manner it was felt that a qualitative comparison of the breadboard test and functional test could be made.

Results of the test (Appendix B) showed that, as in the case of the breadboard tests, "Olive Leaf," "Ivory," "Camay," and "Safeguard" soaps were the best performers insofar as avoiding the problem of excess sudsing. It was also confirmed in this series of tests that without man in the loop, the separator evaluation is very conservative while tests with wastewater from actual showers indicated no suds buildup or carryover with the above noted soaps. Since these soaps provide the full spectrum of desirable soaps, i.e., liquid, standard, beauty cream, and bactericidal, they were recommended for the verification testing at the Johnson Space Center, Houston, Texas.

TASK 4 - VERIFICATION
LIQUID/GAS SEPARATOR PERFORMANCE VERIFICATION TESTS

Introduction

The liquid/gas separator performance verification tests were conducted in the Advanced ECS Laboratory of the Environmental Control and Life Support Systems Branch in Building 7 of NASA-JSC, Houston, Texas. A "deliverable hardware" (Fig. 14) of the refined LGS was installed in the zero-g whole body shower two-phase flow system on January 12, 1976. This installation was "readiness checked" for a series of verification tests with actual test subjects from January 13 through 16, 1976.

Test Objective

The objective of the LGS testing at JSC was to verify the test results and compare with testing previously conducted at Martin Marietta Corporation, Denver Division. The manufacturer's testing consisted of more than 60 test runs which culminated in a NASA-approved configuration and the tentative selection of four different soaps (Olive Leaf, Ivory, Camay, and Safeguard). A "free choice" of these soaps was offered each of the test subjects.

Test Hardware Description

Test hardware consisted of all the original elements of the zero-g whole body shower with the exception of the liquid gas separator. This element was a new one that had been redesigned to provide for a wider choice of soaps without generating excess suds and "carryover" into the air outlet. See Tables 3 and 4 for a comparison of the original and revised separators. A functional schematic, Figure 2, shows the relationship of the separator to the rest of the system.

The ZGWBS includes a lighted shower enclosure (stall) with a self-latching transparent door and associated equipment to support the bathing function in the stall. Heated air is forced into the shower stall by a blower. A vortex type liquid/gas separator is connected between the shower stall and the blower inlet to prevent water droplets or soap suds from returning

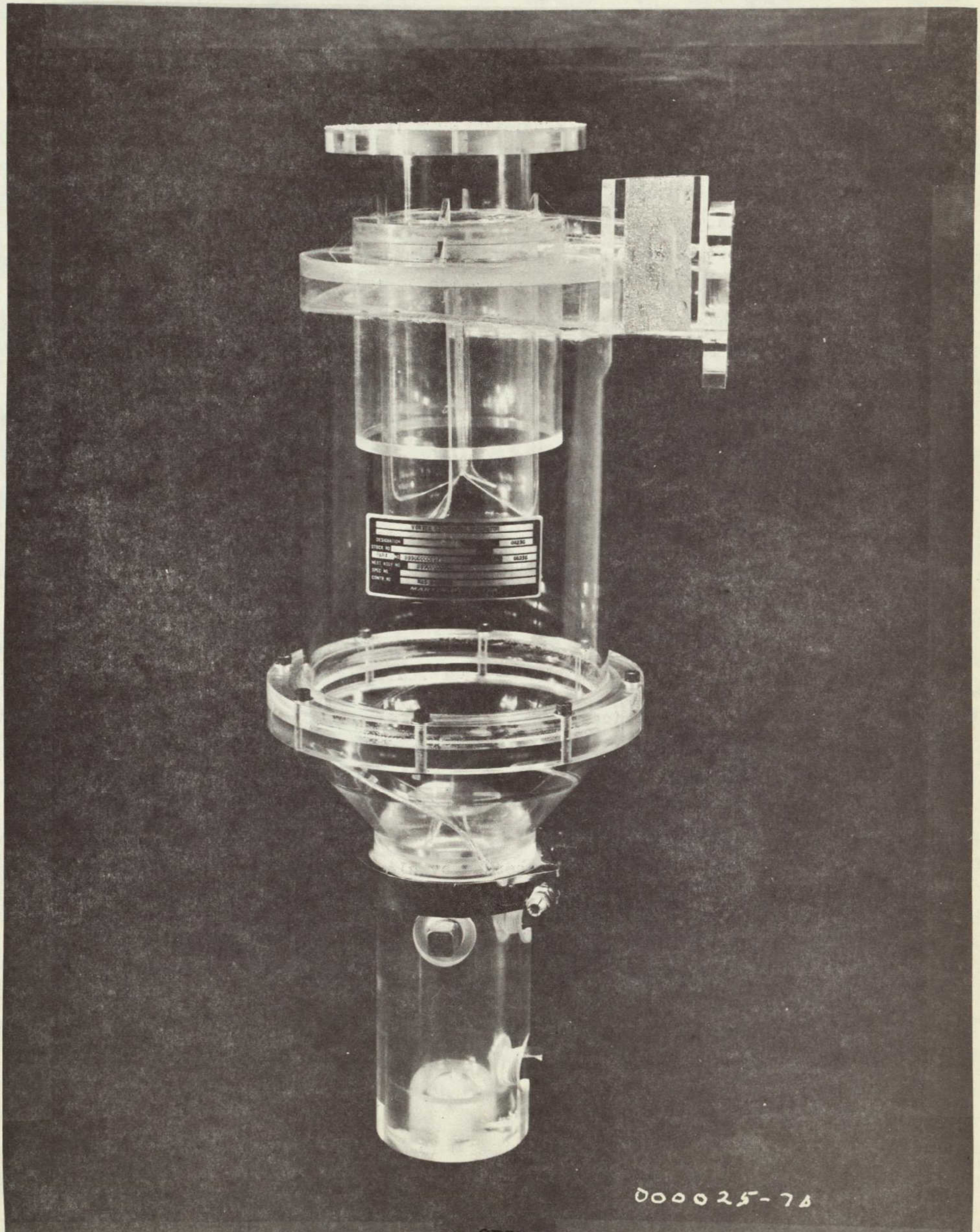


Figure 14 Deliverable Hardware

to the shower stall through the blower. A bleed circuit is included in the air loop to control CO_2 levels within the stall. The water that accumulates in the liquid/gas separator sump is periodically removed by a small gear pump that is automatically activated by liquid level sensors in the sump. Fresh water is introduced to the shower stall by a hand-held nozzle that is manually operated by a pushbutton built into the nozzle. The nozzle assembly contains a commercially available flow orifice that is designed for a small flow rate, typically 22.1 ml/sec (0.35 gpm) at 1130 mmHg (20 psig). Shower water is manually removed from the stall with a hand-held vacuum pickup that is attached with a flexible hose to the two-phase side of the liquid/gas separator. The ZGWBS also contains panel-mounted instrumentation and controls for observing and maintaining its operation.

Facility Description

To provide the appropriate operating conditions for the ZGWBS hardware, Building 7 Advanced ECS Lab support systems were made available. These laboratory systems, along with the ZGWBS components they supported are listed below.

ZGWBS Component	Laboratory Subsystem
Air Blower, Water Pump, Air Heater, Lighting, and other Power Devices	Electrical Power Control Panel
Hot Water Supply	Chilled Water Panel and Water Heater
Data (water temperature and water flow)	Brown Temperature Recorder and Flow Totalizer

The following parameters were recorded by electronic and mechanical measuring instruments. The data was displayed real time in the vicinity of the ZGWBS and was hand recorded on test forms.

Item No.	Description	Displayed Range and Accuracy
1	Energy consumption	0-1000$\pm$1 watt hrs (0-3412$\pm$3.4 BTU)
2	Air flow rate	0-.0472 m^3/sec (0-100$\pm$5 cfm)
3	Air temperature set point	294-332$\pm$2 °K (70-120$\pm$5°F)
4	Shower duration	0-15 minutes $\pm$ 3 minutes

Item No.	Description	Displayed Range and Accuracy
5	Shower water temperature	289-339±2°K (60-150±2°F)
6	Total water used	Flowtimes ± 0.1 sec
7	Mass water used	0-4.53±.04 Kg (0-10±0.1 lb)
8	Mass and type of cleansing agent	0-10±0.1 g
9	Time shower nozzle used	0-20 minutes ± 1 second
10	Bleed air flow rate	0-.0094 m^3/sec (0-20±0.5 cfm)
11	Shower stall air temperature	294-322±2°K (70-120±5°F)
12	Chemical analysis of used shower water	By JSC Chem. Laboratory

As had been recommended by NASA technical representatives, the effectiveness of the liquid/gas separator was determined by simply observing the clear section of the separator air outlet for presence of liquid carry-over.

Test Description

Following the ground rules established for previous ZGWBS testing, each test subject was given complete freedom of water usage and showering time. Subjects, males and females, could also use up to 25 cc (1.5 in.^{3}) of liquid Olive Leaf dispensed from a syringe. A choice of three different (Ivory, Camay, and Safeguard) bar soaps to be used ad lib was also offered. The water and shower stall air temperatures were preset and controlled to approximately 313°K (105°F), a temperature determined from experience to be best for comfort. The subjects were requested to sequentially wet and soap their bodies and rinse until they thought all residual soap was removed. After the shower was completed, the subjects were asked to remove water droplets from stall surfaces with the vacuum pickup. However, they could open the stall door and towel dry prior to stall cleaning. Hair washing was another option to the subjects.

Various panel instruments were read by the test subjects before and after each shower. The water collected from the shower stall (recovered water) through the liquid/gas separator was weighed to determine the amount. A graphic record of water delivered to the ZGWBS was maintained. The temperature of the water being delivered to the stall and the stall air were measured and recorded. In general, the test procedure was in accordance with the previous tests conducted on this shower system with the exception that a visual observation was made of the air outlet of the separator. This activity was supported by an assistant to the technical monitor or the technical monitor himself to determine that there was no "carryover" of liquid.

Data Analysis and Results

The results of the shower tests were positive in that no liquid carryover into the liquid/gas separator air outlet was observed. Observations were made during all the 24 showers that were taken and included the use of all the soaps that had been recommended for test. Test data sheets have been included in this report as Appendix C and include various parameters similar to previous testing conducted at MMC as well as JSC. A review of these parameters shows that they fall well within the limits of the previous testing. However, it was found that subject comments centered on their preference for one of the three bar soaps rather than the Olive Leaf liquid soap. In view of a liquid soap to bar soap weight ratio of approximately four to one, the use of bar soap would be indicated. Furthermore, the concern of bacterial growth on soap and its subsequent spreading has been found to be without foundation (Ref. 3).

CONCLUSIONS AND RECOMMENDATIONS

The new information and conclusions resulting from this contract are as follows.

1. The retrofit LGS effectively separates liquid/suds from air without carryover for the four soaps that have been recommended for use.

2. Soaps which have been demonstrated are Olive Leaf, Ivory, Camay, and Safeguard. They cover the field of liquid, standard, beauty cream, and bactericidal soaps.

3. The vacuum pick-up head and flexible hose contribute much more significantly to suds generation than does the LGS itself. A movie film has been made to document this phenomena.

4. Wastewater which comes from actual use of a shower is much less likely to generate excess sudsing than simulated wastewater made up of tap water and soap. It is apparent that the body oil and salts tend to reduce the sudsing ability of soap/water solutions. Therefore, LGS/system tests should include man in the loop.

5. In the design of future flow systems for ZBWB showers, particular attention should be given to minimizing agitation of the two-phase flow between the vacuum pick-up head and the separator entrance.

6. Tests of the ZGWBS should be conducted under simulated zero-g (KC-135) to confirm the functions of the new separator and the entire ZGWBS flow system.

7. Comparison tests of bacterial activity over an extended period in various parts of the flow system should be conducted with several choices of soap. Such tests could be readily conducted in the existing laboratory setup.

References

1. *Technology Development for a Zero-Gravity Whole Body Shower*, NASA CR-112006. A. A. Rosener, et al

2. *The Application of Gas/Liquid Cyclone in Oil Refining*, Trans. ASME, pp 245-251, January 1958, Van Dongen, J. R. J. and TerLinden, A. J.

3. *Bacteriological Studies Relating to Handwashing*, American Journal of Public Health, Vol. 55, No. 6, June 1965, E. A. Bannan, M. S. and L. F. Judge, PhD.

APPENDIX A - DEVELOPMENT TEST

DATE 04-24-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 1

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE large slugs rapidly picked up

TYPE OF SOAP Neutrogena Rainbath

CONCENTRATION OF SOAP 20 ml/3785 ml water (1.5 in.^{3}/231 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous Pump Operation

TEST OBJECTIVE:

To verify test setup to be operational.

TEST RESULT:

The soapy water mixture entered the two phase inlet and reached the sump after 3/4 revolution. Suds quickly generated and suds carryover was inevitable.

CONCLUSION:

Test setup is adequate. Neutrogena soap is a "high sudser".

DATE 04-24-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 2

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE large slugs of water rapidly picked up

TYPE OF SOAP Phisohex

CONCENTRATION OF SOAP 20 ml/3785 ml water (1.5 $in.^3$/231 $in.^3$)

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

To compare sudsing of Phisohex soap to Neutrogena.

TEST RESULT:

This resulted in lower suds and a lower rate of suds buildup, although suds buildup was well above the vortex breaker plate at an undesirable level.

CONCLUSION:

Rapid pickup of soapy water creates excessive suds.

DATE 04-24-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 3

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE a steady rate of 379 ml/min. (23 in.^{3}/min.)

TYPE OF SOAP Neutrogena Rainbath

CONCENTRATION OF SOAP 20 ml/3785 ml H_2O (1.5 in.^{3}/231 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

At this time it was felt that a rate of water flow into the separator should be similar to that of the SSP shower. A tentative flow rate of 1 gallon/10 min. was established.

TEST RESULT:

A steady buildup of suds occurred to a point of unacceptability.

CONCLUSION:

System created too much suds and an effort should be made to isolate the problem area. Carryover was inevitable.

DATE 04-24-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 4

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE: vacuum line was bypassed

AIR FLOW THROUGH SEPARATOR: 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET: 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW: .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE: 379 ml/min. (23 in.^{3}/min.)

TYPE OF SOAP: Neutrogena Rainbath

CONCENTRATION OF SOAP: 20 ml/3785 ml water (1.5 in.^{3}/231 in.^{3})

PRESSURE DROP ACROSS SEPARATOR: 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE: 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

It was felt that the suds generation could be in the corrugated vacuum pickup hose. Therefore, the soapy water was introduced directly into the two phase inlet duct.

TEST RESULT:

This resulted in a very low sudsing effect in the separator.

CONCLUSION:

This isolated the sudsing problem to be in the vacuum pickup hose, or in obstruction (soap inlet fitting).

DATE 04-25-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 5

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE: 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR: 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET: 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW: .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE: 758 ml/min (46 in.^{3}/min)

TYPE OF SOAP: Neutrogena Rainbath

CONCENTRATION OF SOAP: 20 ml soap/3785 ml water (1.5 in.^{3}/231 in.^{3})

PRESSURE DROP ACROSS SEPARATOR: N/A

ΔP FROM SEPARATOR INLET TO ATMOSPHERE: 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

To avoid obstructions in the separator inlet duct, the test setup was modified by use of a transition plate (in place of inlet duct) for the vacuum hose/separator interface.

TEST RESULT:

Suds began to buildup immediately. There was no actual suds carryover, but the suds were thick and stable up to the cone/cylinder interface.

CONCLUSION:

It was observed that a great deal of turbulence occurred at the hose/separator interface. The entry flow must be smooth with no abrupt edges.

DATE 04-25-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 6

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE 758 ml/min.(46 $in.^3$/min)

TYPE OF SOAP Neutrogena Rainbath

CONCENTRATION OF SOAP 20 ml soap/3785 ml water (1.5 $in.^3$/231 $in.^3$)

PRESSURE DROP ACROSS SEPARATOR N/A

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

A straight tube used in place of vacuum hose to determine effect of hose convolutions on sudsing. Test setup the same as in Test #5.

TEST RESULT:

Only a slight improvement over Test #5 was observed.

CONCLUSION:

Hose convolutions added to sudsing, but most were caused by the sharp edged entrance configuration.

DATE 04-28-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 7

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE 0.014 m^3/sec (30 cfm)

AIR FLOW THROUGH SEPARATOR 0.041 m^3/sec(87 cfm)(includes 40 cfm makeup air)

VELOCITY AT SEPARATOR INLET 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE 758 ml/min. (46 in.^{3}/min)

TYPE OF SOAP Neutrogena Rainbath

CONCENTRATION OF SOAP 20 ml soap/3785 ml water (1.5 in.^{3}/231 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.
Corrugated hose configuration.

TEST OBJECTIVE:

Effort was made to duplicate velocity in vacuum hose as in present shower.

TEST RESULT:

Slugging occurred in the hose and was not efficient in picking up water.

CONCLUSION:

Test could not be completed. Flow rate too low in vacuum hose; noneffective.

DATE 04-28-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 8

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET 19.1 m/sec (3760 fpm)(inlet area = 2.7 $in.^2$)

AIR INJECTION FLOW .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE 758 ml/min. (46 $in.^3$/min)

TYPE OF SOAP Neutrogena Rainbath

CONCENTRATION OF SOAP 20 ml soap/3785 ml water (1.5 $in.^3$/231 $in.^3$)

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

To determine effect of inlet velocity (at "choke" point) on sudsing.

TEST RESULT:

No suds carryover, but entry vanes did have some suds adhering to them. Suds movement up the inside wall of air outlet measured 10 cm (4 in.) Suds buildup was thick up to the cone/cylinder interface.

CONCLUSION:

Compared to other inlet velocities, it appears that inlet velocity has little if any effect.

DATE 04-28-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 9

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET 24.5 m/sec (4830 fpm) (inlet area = 2.1 in.^{2})

AIR INJECTION FLOW .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE 758 ml/min. (46 in.^{3}/min)

TYPE OF SOAP Neutrogena Rainbath

CONCENTRATION OF SOAP 20 ml soap/3785 ml water (1.5 in.^{3}/231 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

To determine effect of inlet velocity (at "choke" point) on sudsing.

TEST RESULT:

No suds carryover.

CONCLUSION:

Although this inlet velocity produced less suds than any other, overall it appears that inlet velocity has little, if any, effect on sudsing.

DATE 04-28-75

TEST NO. 10

TEN INCH DIAMETER SEPARATOR

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET 43.4 m/sec(8550 fpm)(inlet area = 1.185 in.^{2})

AIR INJECTION FLOW .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE 758 ml/min.(46 in.^{3}/min)

TYPE OF SOAP Neutrogena Rainbath

CONCENTRATION OF SOAP 20 ml soap/3785 ml water(1.5 in.^{3}/231 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

To determine effect of inlet velocity (at "choke" point) on sudsing.

TEST RESULT:

No suds carryover but suds were observed up to 10 cm (4 in.) inside air outlet tube. Suds buildup was up to top of sump.

CONCLUSION:

Compared to other inlet velocities, it appears that velocity has little if any effect.

DATE 04-28-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 11

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE: Vacuum pickup line bypassed

AIR FLOW THROUGH SEPARATOR: 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET: 43.4 m/sec(8550 fpm) (inlet area = 1.185 in.^{2})

AIR INJECTION FLOW: .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE: 758 ml/min. (46 in.^{3}/min)

TYPE OF SOAP: Neutrogena Rainbath

CONCENTRATION OF SOAP: 20 ml soap/3785 ml water (1.5 in.^{3}/231 in.^{3})

PRESSURE DROP ACROSS SEPARATOR: 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE: 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

To determine effect of velocity (at "choke" point/without vacuum hose) on sudsing.

TEST RESULT:

No buildup of suds or carryover.

CONCLUSION:

With a steady soapy water flow rate and with a smooth inlet line, there is no suds buildup even with a high sudser like Neutrogena soap. Velocity has little, if any, effect.

DATE 04-28-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 12

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE 758 ml/min. (46 in.^{3}/min)

TYPE OF SOAP Neutrogena Rainbath

CONCENTRATION OF SOAP 20 ml soap/3785 ml water (1.5 in.^{3}/231 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

To determine effect of inlet velocity (at "choke" point) on sudsing.

TEST RESULT:

There was no carryover. Suds were observed in the air outlet tube up to 10 cm (4 in.)from the base. Suds buildup reached a level that was 2.54 cm (1 in.) above sump/cone interface.

CONCLUSION:

Compared to other inlet velocities, it appears that inlet velocity has little, if any, effect.

DATE 04-29-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 13

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE 758 ml/min. (46 $in.^3$/min)

TYPE OF SOAP Neutrogena Rainbath

CONCENTRATION OF SOAP 20 ml soap/3785 ml water (1.5 $in.^3$/231 $in.^3$

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous Pump operation.
Distilled water.

TEST OBJECTIVE:

Water quality effect on sudsing.

TEST RESULT:

Suds buildup was beyond cone/cylinder interface. Suds entered the air outlet in large quantities with a gradual movement up through the air outlet duct.

CONCLUSION:

Distilled water generated far more sudsing than Denver water.

DATE 04-29-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 14

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE: 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR: 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET: 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW: .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE: 758 ml/min. (46 in.^{3}/min)

TYPE OF SOAP: Miranol (C2M-SF concentrate)

CONCENTRATION OF SOAP: 20 ml soap/3785 ml water (1.5 in.^{3}/231 in.^{3})

PRESSURE DROP ACROSS SEPARATOR: 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE: 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.
Distilled water.

TEST OBJECTIVE:

To compare sudsing of Miranol to that of Neutrogena with distilled water.

TEST RESULT:

Soap suds buildup was more rapid and bubble size was larger.

CONCLUSION:

Mineral-free water creates a much larger sudsing potential.

DATE 04-29-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 15

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE 758 ml/min. (46 in.^{3}/min)

TYPE OF SOAP Phisohex

CONCENTRATION OF SOAP 20 ml soap/3785 ml water (1.5 in.^{3}/231 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.
Distilled water.

TEST OBJECTIVE:

To compare sudsing of Phisohex to that of Neutrogena and Miranol.

TEST RESULT:

No suds buildup or carryover, ideal operation.

CONCLUSION:

Illustrates typical operation with a low sudsing soap, and steady flow rate.

DATE 04-29-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 16

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE	0.033 m^3/sec (70 cfm)
AIR FLOW THROUGH SEPARATOR	0.041 m^3/sec (87 cfm)
VELOCITY AT SEPARATOR INLET	13.2 m/sec (2600 fpm)
AIR INJECTION FLOW	.0080 m^3/sec (17 cfm)
SOAP/WATER FLOW RATE	slugging (rapid removal of water)
TYPE OF SOAP	Phisohex
CONCENTRATION OF SOAP	20 ml soap/3785 ml water (1.5 in.^{3}/231 in.^{3})
PRESSURE DROP ACROSS SEPARATOR	0.37 mmHg (0.2 in. H_2O)
ΔP FROM SEPARATOR INLET TO ATMOSPHERE	18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

Determine the effects of slugging with Phisohex soap.

TEST RESULT:

No carryover although suds buildup was excessively high.

CONCLUSION:

Optimum operation of the separator can best be obtained with use of a steady flow.

DATE 04-29-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 17

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE slugging (rapid removal of water)

TYPE OF SOAP Miranol (C2M-SF concentrate)

CONCENTRATION OF SOAP 20 ML Soap/3785 ML Water (1.5 in.^{3}/231 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

Determine effects of slugging with Miranol soap.

TEST RESULT:

Rapid suds buildup and carryover.

CONCLUSION:

Slugging operation with Miranol creates an unsatisfactory sudsing condition.

DATE 04-29-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 18

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE slugging (rapid removal of water)

TYPE OF SOAP Neutrogena Rainbath

CONCENTRATION OF SOAP 20 ml soap/3785 ml water(1.5 $in.^3$/231 $in.^3$)

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

Determine effects of continuous slugging with Neutrogena soap.

TEST RESULT:

Rapid suds buildup and carryover.

CONCLUSION:

Slugging with Neutrogena creates an unsatisfactory condition.

DATE 05-01-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 19

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE slugging (rapid removal of water)

TYPE OF SOAP Neutrogena Rainbath

CONCENTRATION OF SOAP 20 ml soap/3785 ml water(1.5 in.^{3}/231 in.

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

Use of a clear, smooth glasstube in place of the corrugated vacuum hose to observe water flow and effects of smooth bore tubing.

TEST RESULT:

There was severe suds buildup and eventual suds carryover.

CONCLUSION:

Slugging operation, even with a smooth bore tube creates an unsatisfactory sudsing condition.

DATE 05-05-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 20

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE	0.033 m^3/sec (70 cfm)
AIR FLOW THROUGH SEPARATOR	0.041 m^3/sec (87 cfm)
VELOCITY AT SEPARATOR INLET	13.2 m/sec (2600 fpm)
AIR INJECTION FLOW	.0080 m^3/sec (17 cfm)
SOAP/WATER FLOW RATE	slugging (rapid removal of water)
TYPE OF SOAP	Ivory Bar Soap
CONCENTRATION OF SOAP	6.6 grams/3785 ml water (1.5 in.^{3}/231 in.^{3})
PRESSURE DROP ACROSS SEPARATOR	0.37 mmHg (0.2 in. H_2O)
ΔP FROM SEPARATOR INLET TO ATMOSPHERE	18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

To observe effects of slugging Ivory soap on sudsing. Glass tube was used.

TEST RESULT:

Suds buildup was half-way up the cone. Small suds were observed in the air outlet tubing (slight amount). Cleanup was very fast.

CONCLUSION:

Low suds soap is a definite improvement over Neutrogena and Miranol C2M-SF.

DATE 05-05-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 21

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE slugging

TYPE OF SOAP Phisohex

CONCENTRATION OF SOAP 20 ml soap/3785 ml water (1.5 in.^{3}/231 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

To determine effects of slugging with use of Phisohex on sudsing. Glass tube was used.

TEST RESULT:

Same as Test #20.

CONCLUSION:

Low sudsing soap is a definite improvement.

DATE 05-14-75

ANTI-FOAMING AGENTS

TEST NO. 22

Three beakers were filled with a sopy water mixture to the same level.

Beaker #1 was clean.

Beaker #2 was coated with silicone grease, all surface area.

Beaker #3 was coated with silicone grease 1.3 cm (1/2-in.) above and below water line.

All beakers were churned violently with individual stirrers.

Soap concentration: 1:189 (Neutrogena Liquid Soap)

Grease - Silicone stop cock grease from Dow Corning.

TEST OBJECTIVE:

To observe effect of a silicone film vs clean surface for suds generation.

TEST RESULT:

Beaker #1: Suds built up and remained stable.
Beaker #2: Suds built up slightly and quickly dissolved.
Beaker #3: Results were similar to Beaker #2, but not quite as good.

CONCLUSION:

Silicone film definitely helps prevent suds buildup in a beaker test.

DATE 05-15-75

ANTI-FOAMING AGENTS

TEST NO. 23

Test No. 22 of 05-14-75 rerun with a soap concentration of 1:50.

NOTE: Beaker #3 eliminated from test.

Silicone stop cock grease from Dow Corning.

TEST OBJECTIVE:

To observe effect of a higher concentration of soap.

TEST RESULT:

Beaker #1: Created a stable buildup of suds.
Beaker #2: Did not create suds.

CONCLUSION:

Silicone film on beaker prevents suds buildup.

ANTI-FOAMING AGENTS

DATE 05-15-75

TEST NO. 24

Repeat of Test #23 with a soap concentration of 1:10.

Silicone stop cock grease from Dow Corning.

TEST OBJECTIVE:

To observe effect of a higher concentration of soap.

TEST RESULT:

Beaker #1: Created a stable buildup of suds.
Beaker #2: Did not create suds.

CONCLUSION:

Silicone film on beaker prevents suds buildup. It appeared that silicone particles were in solution with water.

DATE 05-16-75

TEST NO. 25

ANTI-FOAMING AGENTS

Soap concentration of 1:10.

Beaker #1: Clean.

Beaker #2: Silicone film.

TEST OBJECTIVE:

To observe effects of a silicone film with adhesive properties. G. E. glass sealant was put on inside surface of beaker.

TEST RESULT:

No difference in soap buildup and stability between Beakers #1 and #2.

CONCLUSION:

Silicone in rubberized form has no apparent effect on suds reduction.

DATE 05-16-75

TEST NO. 26

ANTI-FOAMING AGENTS

Beaker #1 - clean glass.

Beaker #2 - silicone greased glass.

TEST OBJECTIVE:

Beaker comparative test with Dow Corning #111 Compound silicone grease.

TEST RESULT:

Suds buildup in greased beaker would slowly take place and quickly dissolve after stirring. Clean beaker had suds buildup and suds were stable.

CONCLUSION:

Silicone grease in a beaker is an effective suds depressant.

DATE 05-20-75

TEST NO.

TEFLON COATING (as a defoaming agent)

TEST OBJECTIVE:

To determine the effectiveness of teflon lining in the prevention of suds formation.

TEST EQUIPMENT:

Teflon lined beaker
Glass stirring rods
Glass beaker (control)

TEST RESULT:

Agitation of the Neutrogena/water solution in both the teflon lined beaker and the glass "control" geaker produced an equal amount of suds. Suds in the two containers were *equally* stable.

CONCLUSION:

Teflon coating as a defoaming agent or antifoaming device is ineffective.

DATE 05-22-75

TEST NO. 28

DOW CORNING #111 SILICONE GREASE
(as a defoaming agent)

TEST OBJECTIVE:

In view of the positive results of beaker tests with silicone grease (05-15 and 05-16-75), the objective of this test was to determine the effectiveness of a coating of silicone grease on the inner surface of the separator.

TEST EQUIPMENT:

DC #111 Silicone Grease
25.4 cm (10-inch) diameter separator and associated test gear
Neutrogena Soap

TEST RESULT:

No visible improvement (reduction) in the amount of sudsing.

CONCLUSION:

It became apparent that the soap/water solution is exposed to such a large quantity of air that it overwhelms the effectiveness of the silicone.

DATE 05-28-75

TEST NO. 29

DOW CORNING DB-100 SILICONE GREASE
(as a defoaming agent)

TEST OBJECTIVE:

Discussions with Dow Corning Technical personnel led to the conclusion that:

(a) their DB-100 silicone grease would be best for our application;

(b) that dispersion of the silicone in the soap water solution was the key to its effectiveness.

DB-100 effectiveness was to be demonstrated in this test.

TEST EQUIPMENT:

DB-100 silicone grease
25.4 cm (10-inch) diameter separator
Brass screen for application of silicone
Associated test gear
Neutrogena soap

TEST RESULT:

The results were positive for approximately one third of the test run. No sudsing above the vortex breaker plate was in evidence. However, after this time it appeared that the coated (DB-100) screen became ineffective and an excess of suds was collected. A visual examination showed the screen had become devoid of the DB-100 which must have eroded away.

CONCLUSION:

Time of effectiveness of such a small area was inadequate.

DATE 05-30-75

TEST NO. 30

TEST WITH ALUMINUM LINER (as an anti-foaming agent)

TEST OBJECTIVE:

To determine the effectiveness of a metallic liner (aluminum) in the prevention of suds formation.

TEST EQUIPMENT:

Aluminum tape
25.4 cm (10-inch) diameter separator
Associated test gear
Neutrogena soap

TEST RESULT:

The test results were negative in that the aluminum tape applied to the inside surface of the separator had no "lessening" effect on suds formation.

CONCLUSION:

An aluminum inner surface of the separator had no effect in lessening the amount of suds formed. This appeared to support the conclusion of Test #28 of 05-22-75.

DATE 05-30-75

ALPHA RADIATION TEST (as a defoaming agent)

TEST NO. 31

TEST OBJECTIVE:

To determine the effectiveness of alpha radiation on the stability of a head of suds in a 400 ml (24.4 in.^{3}) beaker.

TEST EQUIPMENT:

Alpha radiation emitters, Static Master 500, Model #36-500, and Model #1C-200. Neutrogena/water filled 400 ml beakers (2) with one for "control".

TEST RESULT:

No visible effect whatsoever was in evidence. The suds were quite stable and remained in this condition when exposed to either of emitters noted above.

CONCLUSION:

Upsetting the energy balance in a soap bubble (suds) system is not practical with the use of self-contained alpha emitter modules.

DATE 05-14-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 32

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE	Vacuum pickup line was bypassed
AIR FLOW THROUGH SEPARATOR	0.041 m^3/sec (87 cfm)
VELOCITY AT SEPARATOR INLET	13.2 m/sec (2600 fpm)
AIR INJECTION FLOW	.0080 m^3/sec (17 cfm)
SOAP/WATER FLOW RATE	600 ml/min. (36.6 in.^{3}/min)
TYPE OF SOAP	Neutrogena
CONCENTRATION OF SOAP	60 ml/3785 ml water (4.5 in.^{3}/231 in.^{3})
PRESSURE DROP ACROSS SEPARATOR	0.37 mmHg (0.2 in. H_2O)
ΔP FROM SEPARATOR INLET TO ATMOSPHERE	18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

To determine effect of soap-to-water concentration on separator operation.

TEST RESULT:

Soap buildup to top of deflector plate.

CONCLUSION: When sump is filled with water, suds are pushed up farther and are then in contact with the vortex air motion, creating more suds. A possible solution would be to allow increased volume for suds growth before reaching deflector plate; this can be accomplished by lengthening sump but keeping water removal rate the same level.

DATE 06-10-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 33

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE	Vacuum line was bypassed
AIR FLOW THROUGH SEPARATOR	0.041 m^3/sec (87 cfm)
VELOCITY AT SEPARATOR INLET	13.2 m/sec (2600 fpm)
AIR INJECTION FLOW	.0080 m^3/sec (17 cfm)
SOAP/WATER FLOW RATE	600 ml/min. (36.6 in.^{3}/min)
TYPE OF SOAP	Neutrogena
CONCENTRATION OF SOAP	40 ml/3785 ml water (3 in.^{3}/231 in.^{3})
PRESSURE DROP ACROSS SEPARATOR	0.37 mmHg (0.2 in. H_2O)
ΔP FROM SEPARATOR INLET TO ATMOSPHERE	18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

To determine effect of soap-to-water concentration on separator operation.

TEST RESULT:

Suds buildup 5.08 cm (2 in.) above top of sump. Soap film on wall of cone up to cone/body interface.

CONCLUSION:

Concentration seems to have no consistent effect on sudsing.

DATE 06-10-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 34

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE: Vacuum line was bypassed

AIR FLOW THROUGH SEPARATOR: 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET: 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW: .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE: 600 ml/min. (36.6 $in.^3$/min)

TYPE OF SOAP: Neutrogena

CONCENTRATION OF SOAP: 20 ml/3785 ml water (1.5 $in.^3$/231 $in.^3$)

PRESSURE DROP ACROSS SEPARATOR: 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE: 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

To determine effect of soap-to-water concentration on separator operation.

TEST RESULT:

Suds buildup level at the vortex breaker plate.

CONCLUSION:

Buildup is less than Test #33.

DATE 06-10-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 35

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE: Vacuum line was bypassed

AIR FLOW THROUGH SEPARATOR: 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET: 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW: .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE: 600 ml/min. (36.6 in.^{3}/min)

TYPE OF SOAP: Neutrogena

CONCENTRATION OF SOAP: 60 ml/3785 ml water (4.5 in.^{3}/231 in.^{3})

PRESSURE DROP ACROSS SEPARATOR: 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE: 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

Repeat of Test #32.

TEST RESULT:

Suds buildup to 5.08 cm (2 in.) above sump and a film of suds on cone sides.

CONCLUSION:

As soap concentration increases, there is a slight increase in sudsing over Test #34 and even less of an increase over Test #33.

DATE 06-10-75

TEST NO. 36

TEN INCH DIAMETER SEPARATOR

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE: Vacuum line was bypassed

AIR FLOW THROUGH SEPARATOR: 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET: 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW: .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE: 3785 ml/12.6 min.(231 in.^{3}/12.6 min)

TYPE OF SOAP: Neutrogena

CONCENTRATION OF SOAP: 60 ml/3785 ml water (4.5 in.^{3}/231 in.^{3})

PRESSURE DROP ACROSS SEPARATOR: 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE: 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

To determine effect of soap/water flowrate on separator operation.

TEST RESULT:

Suds buildup to the vortex breaker plate.

CONCLUSION:

A change in steady flow rate has little effect on sudsing.

DATE 06-10-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 37

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE: Vacuum line was bypassed

AIR FLOW THROUGH SEPARATOR: 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET: 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW: .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE: 3785 ml/9.5 min. (231 in.^{3}/9.5 min)

TYPE OF SOAP: Neutrogena

CONCENTRATION OF SOAP: 60 ml/3785 ml (4.5 in.^{3}/231 in.^{3})

PRESSURE DROP ACROSS SEPARATOR: 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE: 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

To determine effect of soap/water flow rate on separator operation.

TEST RESULT:

Suds buildup to underside of breaker plate.

CONCLUSION:

A change in steady flow rate has little effect on sudsing.

DATE 06-10-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 38

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE 262 ml/min (average shower) (15.6 in.^{3}/m

TYPE OF SOAP "Irish Spring" bar soap

CONCENTRATION OF SOAP 5.8 grams/2765 ml water (0.20 oz/169 in

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.
Corrugated hose.

TEST OBJECTIVE:

To test effect of bar soap on separator performance.

TEST RESULT:

Rapid suds buildup, test not completed.

CONCLUSION:

Test should be run with actual shower water where body oils have a chance to break down suds.

DATE 06-11-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 39

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 in.^{3}/min)

TYPE OF SOAP Ivory

CONCENTRATION OF SOAP 6.5 grams/2765 ml water(0.23 oz/169 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

To test effect of Ivory bar soap on separator performance.

TEST RESULT:

No suds buildup if pump is working continuously.

CONCLUSION:

Appears to be a low sudsing soap.

DATE 06-12-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 40

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE: 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR: 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET: 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW: .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE: 262 ml/min (15.6 $in.^3$/min)

TYPE OF SOAP: Neutrogena

CONCENTRATION OF SOAP: 20 ml/2765 ml water (1.5 $in.^3$/169 $in.^3$)

PRESSURE DROP ACROSS SEPARATOR: 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE: 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.
Glass inlet tube.

TEST OBJECTIVE:

To determine sudsing effect when an optimized (15 deg) inlet transition is utilized.

TEST RESULT:

Suds buildup still excessive; 10.2 cm (4 in.) above sump. Evidence of less turbulence in inlet section.

CONCLUSION:

Inlet transition fabricated should be used for future tests.

DATE 06-12-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 41

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE Vacuum line bypassed

AIR FLOW THROUGH SEPARATOR 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 $in.^3$/min)

TYPE OF SOAP Neutrogena

CONCENTRATION OF SOAP 20 ml/2765 ml water (1.5 $in.^3$/169 $in.^3$)

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

To determine the effect of bypassing the vacuum pickup hose.

TEST RESULT:

No suds buildup.

CONCLUSION:

System prior to separator creates majority of suds.

DATE 06-12-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 42

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 in.^{3}/min)

TYPE OF SOAP Olive Leaf

CONCENTRATION OF SOAP 20 ml/2765 ml/water (1.5 in.^{3}/169 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.
Glass inlet tube

TEST OBJECTIVE:

Different soap.

TEST RESULT:

No suds buildup.

CONCLUSION:

Olive Leaf is a low sudsing soap and can be recommended for shower usage.

DATE 06-12-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 43

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 in.^{3}/min)

TYPE OF SOAP Irish Spring

CONCENTRATION OF SOAP 5.8 grams/2765 ml water (0.20 oz/169 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.

TEST OBJECTIVE:

Different soap was used.

TEST RESULT:

No suds carryover or buildup.

CONCLUSION:

Irish Spring can be considered a low sudsing soap.

DATE 06-12-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 44

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE slugging condition

TYPE OF SOAP Olive Leaf

CONCENTRATION OF SOAP 20 ml/2765 H_2O (1.5 $in.^3$/169 $in.^3$)

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.
Glass inlet tube.

TEST OBJECTIVE:

Slugging of Olive Leaf soap.

TEST RESULT:

Suds buildup was high, but no suds carryover.

CONCLUSION:

Slugging should be avoided if possible.

DATE 06-12-75

TEN INCH DIAMETER SEPARATOR

TEST NO. 45

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE 0.033 m^3/sec (70 cfm)

AIR FLOW THROUGH SEPARATOR 0.041 m^3/sec (87 cfm)

VELOCITY AT SEPARATOR INLET 13.2 m/sec (2600 fpm)

AIR INJECTION FLOW .0080 m^3/sec (17 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 in.^{3}/min)

TYPE OF SOAP Olive Leaf

CONCENTRATION OF SOAP 40 ml/2765 ml water (3 in.^{3}/169 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 18.64 mmHg (10 in. H_2O)

REMARKS:

Continuous pump operation.
Glass inlet tube.

TEST OBJECTIVE:

Results of a higher concentration.

TEST RESULT:

No suds buildup.

CONCLUSION:

Low sudsing soap is desirable.

DATE 06-13-75

TEST NO. 46

BREADBOARD MODEL

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm) (glass tube)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 18.5 m/sec (3650 fpm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 in.^{3}/min)

TYPE OF SOAP Olive Leaf

CONCENTRATION OF SOAP 20 ml/2765 ml H_2O (1.5 in.^{3}/169 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 2.31 mmHg (1.25 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE ____

REMARKS:

Water level in sump was maintained as in actual shower.

TEST OBJECTIVE:

Separator operation and checkout.

TEST RESULT:

No suds buildup past the deflector plate.

CONCLUSION:

No problem with steady flow.

DATE 06-13-75

BREADBOARD MODEL

TEST NO. 47

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm) (glass tube)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 18.5 m/sec (3650 fpm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 in.^{3}/min)

TYPE OF SOAP Olive Leaf

CONCENTRATION OF SOAP 40 ml/2765 ml H_2O (3 in.^{3}/169 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 2.31 mmHg (1.25 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE

REMARKS:

Water level in sump was maintained.

TEST OBJECTIVE:

Soap concentration doubled over previous test.

TEST RESULT:

Soap suds buildup and carryover.

CONCLUSION:

If pump were allowed to operate continuously, there would be no suds build-up.

DATE 06-13-75

BREADBOARD MODEL

TEST NO. 48

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm)(glass tube)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 18.5 m/sec (3650 fpm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE slugging

TYPE OF SOAP Olive Leaf

CONCENTRATION OF SOAP 20 ml/2765 ml H_2O (1.5 in.^{3}/169 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 2.31 mmHg (1.25 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE

REMARKS:

Water level in sump was maintained.

TEST OBJECTIVE:

Slugging with Olive Leaf.

TEST RESULT:

Suds buildup severe, but no carryover when pump was switched to continuous operation.

CONCLUSION:

Low sudsing soap appears to be the answer to the carryover problem.

DATE 06-13-75

BREADBOARD MODEL

TEST NO. 49

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm)(glass tube)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 18.5 m/sec (3650 fpm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 in.^{3}/min)

TYPE OF SOAP Irish Spring

CONCENTRATION OF SOAP 5.8 grams/2765 ml H_2O (0.20 oz/169 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 2.31 mmHg (1.25 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE

REMARKS:

Water level in sump was maintained.

TEST OBJECTIVE:

To compare Irish Spring to Olive Leaf soap.

TEST RESULT:

Rapid suds buildup with eventual carryover.

CONCLUSION:

Use of soap in actual shower would determine if it is acceptable. Body oils would reduce sudsing.

DATE 06-13-75

BREADBOARD MODEL

TEST NO. 50

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm)(glass tube)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 18.5 m/sec (3650 fpm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 $in.^3$/min)

TYPE OF SOAP Lux

CONCENTRATION OF SOAP 6.9 grams/2765 ml H_2O (0.237 oz/169 $in.^3$)

PRESSURE DROP ACROSS SEPARATOR 2.31 mmHg (1.25 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE

REMARKS:

Water level in sump was maintained.

TEST OBJECTIVE:

To compare Lux to Olive Leaf soap.

TEST RESULT:

Rapid suds buildup with eventual carryover.

CONCLUSION:

May be suitable if soap were used in a shower where body oils would play a part.

DATE 06-13-75

BREADBOARD MODEL

TEST NO. 51

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm) (glass tube)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 18.5 m/sec (3650 fpm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 in.^{3}/min)

TYPE OF SOAP Jergens bar soap

CONCENTRATION OF SOAP 6.1 grams/2765 ml H_2O (0.21 oz/169 in.^{3}

PRESSURE DROP ACROSS SEPARATOR 2.31 mmHg (1.25 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE

REMARKS:

Water level in sump was maintained.

TEST OBJECTIVE:

To compare Jergens to Olive Leaf soap.

TEST RESULT:

Rapid suds buildup and eventual carryover.

CONCLUSION:

May be suitable if soap were in contact with body oils.

DATE 16-13-75

BREADBOARD MODEL

TEST NO. 52

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm) (glass tube)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 18.5 m/sec (3650 fpm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 $in.^3$/min)

TYPE OF SOAP Ivory

CONCENTRATION OF SOAP 6.5 grams/2765 ml H_2O (0.224 oz/169 $in.^3$)

PRESSURE DROP ACROSS SEPARATOR 2.31 mmHg (1.25 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE

REMARKS:

Water level in sump was maintained.

TEST OBJECTIVE:

To compare Ivory bar soap to Olive Leaf soap.

TEST RESULT:

Rapid suds buildup, although slower than Jergens, Lux, Irish Spring. Eventual carryover.

CONCLUSION:

May be suitable if suds were in contact with body oils.

DATE 06-16-75

BREADBOARD MODEL

TEST NO. 53

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm) (Glass tube)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 18.5 m/sec (3650 fpm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 in.^{3}/min)

TYPE OF SOAP Olive Leaf

CONCENTRATION OF SOAP 40 ml/2765 ml H_2O (3.0 in.^{3}/169 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 2.31 mmHg (1.25 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE

REMARKS:

Water level in sump was maintained.

TEST OBJECTIVE:

To determine effect of mixing of soap and water by washing of hands.

TEST RESULT:

Mixing seems to have little or no effect.

CONCLUSION:

Mixing of soap and water by any means should be suitable for tests. Salts and oils from surface of hands do not affect sudsing.

DATE 06-16-75

BREADBOARD MODEL

TEST NO. 54

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm)(glass tube)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 18.5 m/sec (3650 fpm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 $in.^3$/min)

TYPE OF SOAP Olive Leaf

CONCENTRATION OF SOAP 40 ml/2765 ml H_2O (3.0 $in.^3$/169 $in.^3$)

PRESSURE DROP ACROSS SEPARATOR 2.31 mmHg (1.25 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE

REMARKS:

Water level in sump was maintained.

TEST OBJECTIVE:

Use of shower water with body oils. (EAS)

TEST RESULT:

Suds were weaker, no suds buildup or carryover.

CONCLUSION:

Body oils break down sudsing effect; tests are extremely conservative when body oils are not taken into account.

DATE 06-16-75

BREADBOARD MODEL

TEST NO. 55

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm) (glass tube)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 18.5 m/sec (3650 fpm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 $in.^3$/min)

TYPE OF SOAP Olive Leaf

CONCENTRATION OF SOAP 40 ml/2765 ml H_2O (3.0 $in.^3$/169 $in.^3$)

PRESSURE DROP ACROSS SEPARATOR 2.31 mmHg (1.25 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE

REMARKS:

Water level in sump was maintained (attempt).

TEST OBJECTIVE:

Sump length doubled in length to 28 cm (11 in.) length.

TEST RESULT:

Suds buildup was rapid, could not distinguish soap from water in sump.

CONCLUSION:

Soap concentration is too high (when body oils are not part of the system).

DATE 06-16-75

BREADBOARD MODEL

TEST NO. 56

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm)(glass tube)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 18.5 m/sec (3650 fpm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 in.^{3}/min)

TYPE OF SOAP Neutrogena

CONCENTRATION OF SOAP 20 ml/2765 ml H_2O (1.5 in.^{3}/169 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 2.31 mmHg (1.25 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE

REMARKS:

Water level in sump was maintained (attempt).

TEST OBJECTIVE:

Neutrogena soap to be used with 28 cm (11 in.) sump.

TEST RESULT:

Suds buildup and eventual carryover. Could not distinguish water from suds in sump.

CONCLUSION:

Neutrogena suds are too stable.

DATE 06-16-75

BREADBOARD MODEL

TEST NO. 57

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm)(glass tube)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 18.5 m/sec (3650 fpm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 in.^{3}/min)

TYPE OF SOAP Irish Spring

CONCENTRATION OF SOAP 5.8 grams/2765 ML H_2O (0.20 oz/169 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 2.31 mmHg (1.25 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE

REMARKS:

Water level in sump was maintained (attempt).

TEST OBJECTIVE:

Extended sump used.

TEST RESULT:

Suds buildup and eventual carryover. Could not distinguish water from suds in sump.

CONCLUSION:

Suds did not break down fast enough to define the water level in sump, therefore the simulation of pump cycling could not be accomplished.

DATE 06-16-75

BREADBOARD MODEL

TEST NO. 58

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm)(glass tube)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 18.5 m/sec (3650 fpm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 in.^{3}/min)

TYPE OF SOAP Irish Spring

CONCENTRATION OF SOAP 4.3 grams/2765 ml H_2O(0.15 oz/169 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 2.31 mmHg (1.25 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE

REMARKS:

Water level in sump was maintained.

TEST OBJECTIVE:

Shower water with Irish Spring (T.J.)

TEST RESULT:

No suds buildup, or carryover.

CONCLUSION:

Body oils have a big effect on sudsing. The same soap concentration run through the separator without body contact would produce rapid suds build-up and eventual suds carryover.

DATE 06-18-75

BREADBOARD MODEL

TEST NO. 59

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm)(glass tube)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 18.5 m/sec (3650 fpm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 in.^{3}/min)

TYPE OF SOAP Neutrogena

CONCENTRATION OF SOAP 20 ml/2765 ml H_2O (1.5 in.^{3}/169 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 2.31 mmHg (1.25 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE

REMARKS:

Water level in sump was maintained; three grams sodium chloride/300 ml H_2O as a defoaming agent with a flow rate of 100 ml/3 minutes.

TEST OBJECTIVE:

To control sudsing with a defoaming agent.

TEST RESULT:

No effect on sudsing.

CONCLUSION:

Suds are stable, flow rate of defoaming agent must be drastically increased which would be detrimental to separator operation due to overloading.

DATE 06-18-75

BREADBOARD MODEL

TEST NO. 60

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm)(glass tube)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 18.5 m/sec (3650 pfm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 $in.^3$/min)

TYPE OF SOAP Neutrogena

CONCENTRATION OF SOAP 20 ml/2765 ml H_2O (1.5 $in.^3$/169 $in.^3$)

PRESSURE DROP ACROSS SEPARATOR 2.31 mmHg (1.25 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE

REMARKS:

Water level in sump was maintained; three grams potassium phosphate/300 ml H_2O as a defoaming agent with a flow rate of 100 ml/3 minutes.

TEST OBJECTIVE:

To try an alternate defoaming agent.

TEST RESULT:

No effect on sudsing.

CONCLUSION:

Suds are too stable and suds surface area is too great.

DATE 06-18-75

BREADBOARD MODEL

TEST NO. 61

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm)(glass tube)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 18.5 m/sec (3650 pfm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 in.^{3}/min)

TYPE OF SOAP Olive Leaf

CONCENTRATION OF SOAP 40 ml/2765 ml H_2O (3 in.^{3}/169 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 2.31 mmHg (1.25 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE

REMARKS:

Water level in sump was maintained; potassium phosphate, 3 grams/300 ml H_2O at a flow rate of 100 ml/3 minutes (defoaming agent).

TEST OBJECTIVE:

To control sudsing with a defoaming agent.

TEST RESULT:

Defoaming agent had little effect on suds control.

CONCLUSION:

A much higher flow rate of defoaming agent would be required for possible defoaming, but the increased rate would overload the separator. This approach was considered unsuccessful.

DATE 06-18-75

BREADBOARD MODEL

TEST NO. 62

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm)(glass tube)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 18.5 m/sec (3650 pfm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 in.^{3}/min)

TYPE OF SOAP Olive Leaf

CONCENTRATION OF SOAP 40 ml/2765 ml H_2O (3 in.^{3}/169 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 2.31 mmHg (1.25 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE

REMARKS:

Water level in sump was maintained. Sodium phosphate 3 grams/300 ml H_2O at a flow rate of 100 ml/3 minutes (defoaming agent).

TEST OBJECTIVE:

To introduce a defoaming agent to the two-phase fluid as it enters the separator.

TEST RESULT:

No effect, rapid suds buildup.

CONCLUSION:

Surface area of suds is extremely large; unacceptably large amounts of defoaming agent would have to be introduced in the system.

DATE 06-18-75

BREADBOARD MODEL

TEST NO. 63

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm)(glass tube)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 18.5 m/sec (3650 pfm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 $in.^3$/min)

TYPE OF SOAP Safeguard

CONCENTRATION OF SOAP 5 grams/2765 ml H_2O (0.17 oz/169 $in.^3$)

PRESSURE DROP ACROSS SEPARATOR 2.31 mmHg (1.25 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE

REMARKS:

Water level in sump was maintained; long sump used.

TEST OBJECTIVE:

Use of a different brand soap for sudsing measurement.

TEST RESULT:

Slow suds buildup, no carryover.

CONCLUSION:

One of the better bar soaps for low sudsing.

DATE 06-18-75

BREADBOARD MODEL

TEST NO. 64

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm) (glass tube)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 18.5 m/sec (3650 fpm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 262 ml/min (15.6 in.^{3}/min)

TYPE OF SOAP Camay

CONCENTRATION OF SOAP 5 grams/2765 ml H_2O (0.17 oz/169 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 2.31 mmHg (1.25 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE

REMARKS:

Water level in sump was maintained; long sump used.

TEST OBJECTIVE:

Use of a different brand soap for sudsing measurement.

TEST RESULT:

Slow suds buildup, no carryover. Simple cleanup in separator after testing.

CONCLUSION:

One of the better bar soaps for low sudsing.

APPENDIX B - FUNCTIONAL CHECKOUT

DATE 11-03-75

TEST NO. 1

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 16.5 m/sec (3270 fpm) (vac. pickup)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 276.5 ml/min (16.5 in.^{3}/min)

TYPE OF SOAP None

CONCENTRATION OF SOAP None

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 16.77 mmHg (9 in. H_2O)

REMARKS:

Used the actual hose and vacuum pickup (loaned to MMC by NASA) instead of the glass tube used during development tests. Water level in sump was maintained by manual switch operation.

TEST OBJECTIVE:

Dry run to checkout flow, pressures and separator functions.

TEST RESULT:

All pressures and flow were normal--ΔP across separator was 0.37 mmHg (0.2 in.) water rather than 2.31 mmHg (1.25 in.) water (instrumentation difference).

CONCLUSION:

System is ready for functional testing.

DATE 11-03-75

TEST NO. 2

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 16.5 m/sec (3270 fpm)(Vac. pickup)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 276.5 ml/min (16.5 $in.^3$/min)

TYPE OF SOAP Ivory (bar)

CONCENTRATION OF SOAP 6.5 grams/2765 ml H_2O (0.224 oz/169 $in.^3$)

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 16.77 mmHg (9 in. H_2O)

REMARKS:

Used the actual hose and vacuum pickup (loaned to MMC by NASA) instead of the glass tube used during development tests. Water level in sump was maintained by manual switch operation.

TEST OBJECTIVE:

To compare deliverable hardware to the prototype.

TEST RESULT:

Suds buildup similar to previous tests on prototype. Rate of buildup more rapid due to corrugated hose. Eventual carryover after 4-1/2 minutes of operation.

CONCLUSION:

1. Performance of deliverable hardware and prototype is similar.
2. As in prototype testing, man must be in the loop to contribute body oil and salts to the wastewater thus breaking down sudsing of the soap and making the test realistic.

DATE 11-04-75

TEST NO. 3

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 16.5 m/sec (3270 fpm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 276.5 ml/min (16.5 in.^{3}/min)

TYPE OF SOAP Ivory (bar)

CONCENTRATION OF SOAP 2.5 grams/2765 ml H_2O (.086 oz/169 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 16.77 mmHg (9 in. H_2O)

REMARKS:

Same as for Test No. 1. Man was added to the loop through the addition of a shower enclosure. Test Subject - EAS

TEST OBJECTIVE:

To evaluate the effectiveness of the separator.

TEST RESULT:

Satisfactory separation of waste water from air/water mixture. No carry-over.

CONCLUSION:

Under real life situation, with man in the loop, wastewater is much less likely to produce sudsing. Separator functions in a satisfactory manner.

DATE 11-04-75

TEST NO. 4

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 16.5 m/sec (3270 fpm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 276.5 ml/min (16.5 $in.^3$/min)

TYPE OF SOAP Irish Spring (bar)

CONCENTRATION OF SOAP 1.5 grams/2765 ml H_2O (.051 oz/169 $in.^3$)

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 16.77 mmHg (9 in. H_2O)

REMARKS:

Same as for Test #3. Test Subject TGJ

TEST OBJECTIVE:

To evaluate the effectiveness of the separator.

TEST RESULT:

Satisfactory separation of wastewater from air/water mixture. No carry-over.

CONCLUSION:

Separator functions in a satisfactory manner.

DATE 11-04-75

TEST NO. 5

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 16.5 m/sec (3270 fpm)

AIR INJECTION FLOW .00235 m^3/sec (5cfm)

SOAP/WATER FLOW RATE 276.5 ml/min (16.5 $in.^3$/min)

TYPE OF SOAP Safeguard (bar)

CONCENTRATION OF SOAP 2.3 grams/2765 ml H_2O (.079 oz/169 $in.^3$)

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 16.77 mmHg (9 in. H_2O)

REMARKS:

Same as for Test #3. Test Subject EAS.

TEST OBJECTIVE:

To evaluate the effectiveness of the separator.

TEST RESULT:

Satisfactory separation of wastewater from air/water mixture. No carry-over.

CONCLUSION:

Separator functions in a satisfactory manner.

DATE 11-05-75

TEST NO. 6

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 16.5 m/sec (3270 fpm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 276.5 ml/min (16.5 in.^{3}/min)

TYPE OF SOAP Camay (bar)

CONCENTRATION OF SOAP 2.6 grams/2765 ml H_2O (.089 oz/169 in.^{3})

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 16.77 mmHg (9 in. H_2O)

REMARKS:

Same as for Test #3. Test Subject EAS.

TEST OBJECTIVE:

To evaluate the effectiveness of the separator.

TEST RESULT:

Satisfactory separation of wastewater from air/water mixture. No carry-over.

CONCLUSION:

Separator functions in a satisfactory manner.

DATE 11-06-75

TEST NO. 7

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 16.5 m/sec (3270 fpm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE 276.5 ml/min (16.5 $in.^3$/min)

TYPE OF SOAP LUX (bar)

CONCENTRATION OF SOAP 3.2 grams/2765 ml H_2O (.109 oz/169 $in.^3$)

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 16.77 mmHg (9 in. H_2O)

REMARKS:

Same as for Test #3. Test Subject EAS.

TEST OBJECTIVE:

To evaluate the effectiveness of the separator.

TEST RESULT:

More suds generated in system than with Ivory, Safeguard, or Camay. Satisfactory operation of separator with no carryover.

CONCLUSION:

Separator functions in a satisfactory manner.

DATE 11-07-75

TEST NO. 8

FIXED PARAMETERS:

AIR FLOW THROUGH VACUUM PICKUP LINE .0165 m^3/sec (35.5 cfm)

AIR FLOW THROUGH SEPARATOR .0188 m^3/sec (40.5 cfm)

VELOCITY AT SEPARATOR INLET 16.5 m/sec (3270 fpm)

AIR INJECTION FLOW .00235 m^3/sec (5 cfm)

SOAP/WATER FLOW RATE single charge, 125 ml (7.45 $in.^3$)

TYPE OF SOAP None

CONCENTRATION OF SOAP None

PRESSURE DROP ACROSS SEPARATOR 0.37 mmHg (0.2 in. H_2O)

ΔP FROM SEPARATOR INLET TO ATMOSPHERE 16.77 mmHg (9 in. H_2O)

REMARKS:

Separator was mounted in an upside-down position.

TEST OBJECTIVE:

To evaluate the separator effectiveness under a -1g condition.

TEST RESULT:

Evidence of vortex formation is clearly visible. Water is centrifuged vertically upward all the way to the sump entrance where a solid column of air prevented any further movement.

CONCLUSION:

Demonstration was satisfactory.

APPENDIX-C VERIFICATION TESTING AT NASA JSC

C-1

Table I

TEST PARAMETERS

Date: 1-12-76

Time: 12:21 Start 12:35 Finish

Amount of Water Used: 2460 ml (.649 gal.

Amount of Soap Used: 1.4 gr (.049 oz.)

Type of Soap Used ✓ Bar ____ Liquid

Soap Identification Safeguard

Air Temp. at Shower Inlet 311°K (100°F)(Previous Test) °F

Water Temperature 308-311°K (95-100°F)(Previous Test) °F

Hair Washed: ____ Yes ✓ No

Visual Check for "Carryover" in Outlet Airstream:

____ Yes ✓ No

Type: ____ Liquid ____ Suds

Quantity: ____ Trace ____ Other

Subject's Comments: J. T. #1A

- Vacuum pick-up works better than the one for the last test series.
- Blower noise seemed excessive.
- The "suction" soap holder is great for bar soaps.

TECHNICAL MONITOR - Nick Lance

Table 1

TEST PARAMETERS

Date:	1-12-76	
Time:	2:38 Start 2:45 Finish	
Amount of Water Used:	2180 ml (0.575 gal.)	
Amount of Soap Used:	1.6 gr (0.056 oz.)	
Type of Soap Used	✓ Bar ____ Liquid	
Soap Identification	IVORY	
Air Temp. at Shower Inlet	311°K (100°F)	°F
Water Temperature	308-311°K (95-100°F)	°F
Hair Washed:	✓ Yes ____ No	

Visual Check for "Carryover" in Outlet Airstream:

____ Yes ✓ No

Type: ____ Liquid ____ Suds

Quantity: ____ Trace ____ Other

Subject's Comments: E.S. #2A

New "Squeegee" configuration is a big improvement over the original design.

TECHNICAL MONITOR - Nick Lance

Table 1

TEST PARAMETERS

Date:	1-12-76
Time:	3:10 Start 3:17 Finish
Amount of Water Used:	2520 ml (0.665 gal.)
Amount of Soap Used:	4.5 ml ~~gr~~ (0.337 in^3)
Type of Soap Used	___ Bar ✓ Liquid
Soap Identification	Olive Leaf
Air Temp. at Shower Inlet	311°K (100°F) °F
Water Temperature	308-311°K (95-100°F) °F
Hair Washed:	___ Yes ✓ No

Visual Check for "Carryover" in Outlet Airstream:

___ Yes ✓ No

Type: ___ Liquid ___ Suds

Quantity: ___ Trace ___ Other

Subject's Comments: N.L. #3A

Squeezy is better than before.
I thought that Olive Leaf was a little difficult to rinse off.

TECHNICAL MONITOR - Nick Lance

Table I

TEST PARAMETERS

Date: 1-12-76

Time: 3:34 Start 3:46 Finish

Amount of Water Used: 3280 ml (0.866 gal.

Amount of Soap Used: 3.1 gr (0.109 oz.

Type of Soap Used: ✓ Bar ____ Liquid

Soap Identification: IVORY

Air Temp. at Shower Inlet: 311°K (100°F) °F

Water Temperature: 308-311°K (95-100°F) °F

Hair Washed: ✓ Yes ____ No

Visual Check for "Carryover" in Outlet Airstream:

____ Yes ✓ No

Type: ____ Liquid ____ Suds

Quantity: ____ Trace ____ Other

Subject's Comments: J.T. (his second shower for 1-12-76) #4A

TECHNICAL MONITOR - Nick Lance

Table I

TEST PARAMETERS

Date:	1-13-76
Time:	9:02 Start 9:10 Finish
Amount of Water Used:	3440 ml (0.909 gal)
Amount of Soap Used:	2.0 gr (0.070 oz.)
Type of Soap Used	✓ Bar ____ Liquid
Soap Identification	SAFEGUARD
Air Temp. at Shower Inlet	____ °F
Water Temperature	____ °F
Hair Washed:	✓ Yes ____ No

Visual Check for "Carryover" in Outlet Airstream:

____ Yes ✓ No

Type: ____ Liquid ____ Suds

Quantity: ____ Trace ____ Other

Subject's Comments: OKH #1

FIRST TIME SAFEGUARD SOAP USED BY THIS SUBJECT. I LIKED THE SOAP - IT LATHERED WELL AND WAS COMFORTABLE TO THE SKIN. BAR SOAP IS PREFERRED BY ME TO THE LIQUID SOAPS BECAUSE OF EASE OF APPLICATION TO THE BODY. THE VACUUM PICK UP SHEARED WATER FROM STALL SURFACE AND DROPLETS FELL TO THE BOTTOM OF STALL RATHER THAN INTO THE PICKUP. IT WAS DIFFICULT TO CLEAN STALL CORNERS.

TECHNICAL MONITOR - Nick Lance

Table 1

TEST PARAMETERS

Date: 1-13-76

Time: 9:27 Start 9:38 Finish

Amount of Water Used: 3490 ml (0.922 gal)

Amount of Soap Used: 1.6 gr (0.056 oz.)

Type of Soap Used: ✓ Bar ___ Liquid

Soap Identification: IVORY

Air Temp. at Shower Inlet: ___ °F

Water Temperature: ___ °F

Hair Washed: ___ Yes ✓ No

Visual Check for "Carryover" in Outlet Airstream:

___ Yes ✓ No

Type: ___ Liquid ___ Suds

Quantity: ___ Trace ___ Other

Subject's Comments: BM #2

1) OVERALL SHOWER - NOT BAD. FAIRLY COMFORTABLE
2) WATER TEMP. ACCEPTABLE, BUT PERSONALLY PREFER WARMER (+5°F). TOWARD END OF RINSING, WATER WAS WARMER AND NICER.
3) INTENSITY OF SPRAY ACCEPTABLE, BUT PREFER STRONER SPRAY
4) SOAP OK - LATHERED AND RINSED WELL.
5) WALL DRYING TAKES A LOT OF ENJOYMENT OUT OF SHOWERING.
6) HANDLE ON VACUUM SOMEWHAT AWKWARD BUT ACCEPTABLE, COULD BE LESS BULKY
7) SHOWER AIR TEMP. ACCEPTABLE. NO DRAFTS - WHICH WAS NICE WHEN DRYING WALLS.

TECHNICAL MONITOR - Nick Lance

Table I

TEST PARAMETERS

Date: 1-13-76

Time: 9:54 Start 10:01 Finish

Amount of Water Used: 1730 ml (0.457 gal.)

Amount of Soap Used: 1.0 gr (0.035 oz)

Type of Soap Used ✓ Bar ___ Liquid

Soap Identification SAFEGUARD

Air Temp. at Shower Inlet ___ °F

Water Temperature ___ °F

Hair Washed: ___ Yes ✓ No

Visual Check for "Carryover" in Outlet Airstream:

___ Yes ✓ No

Type: ___ Liquid ___ Suds

Quantity: ___ Trace ___ Other

Subject's Comments: RPR # 3

1) TEMP. COMFORTABLE
2) SOAP PROVIDED GOOD LATHER FOR WASHING WITHOUT WASHCLOTH. LATHER RINSED OFF EASILY
3) I FELT I HAD USED ADEQUATE WATER FOR RINSING, WATER WAS A LITTLE COLD AT BEGINNING (WET DOWN)
4) TIME REQUIRED FOR WATER CLEANUP SEEMED LONG, WATER PICKUP WORKED VERY WELL, HOWEVER THE AREA IT COVERS IS SO SMALL IT TAKES A LONG TIME FOR WATER CLEANUP
5) SOAP HOLDER WORKED WELL
6) SHOWER DOOR LATCH (MAGNETIC) SHOULD REQUIRE MORE FORCE TO OPEN SO THAT DOOR WON'T OPEN DURING CLEANUP.
7) NOISE LEVEL WAS NOT OBJECTIONABLE.

TECHNICAL MONITOR — Nick Lance

Table 1

TEST PARAMETERS

Date: 1-13-6

Time: 10:10 Start 10:21 Finish

Amount of Water Used: 1550 ml (0.409 gal

Amount of Soap Used: 20ml ~~gr~~ (1.5 in^3)

Type of Soap Used ____ Bar ✓ Liquid

Soap Identification Olive Leaf

Air Temp. at Shower Inlet 311°K (100°F) °F

Water Temperature 308-311°K (95-100°F) °F

Hair Washed: ____ Yes ✓ No

Visual Check for "Carryover" in Outlet Airstream:

____ Yes ✓ No

Type: ____ Liquid ____ Suds

Quantity: ____ Trace ____ Other

Subject's Comments: J. T. #4

- Same comments as on 1-12-76
- Water pressure could be higher to wash off the suds.
- Not as noisy to-day.

TECHNICAL MONITOR- Nick Lance

Table 1

TEST PARAMETERS

Date:	1-13-76
Time:	10:34 Start 10:49 Finish
Amount of Water Used:	3710 ml (0.980 gal.
Amount of Soap Used:	2.2 gr (0.077 oz)
Type of Soap Used	✓ Bar ___ Liquid
Soap Identification	Safeguard
Air Temp. at Shower Inlet 311°K	(100 °F) °F
Water Temperature 308-311°K	(95-100 °F) °F
Hair Washed:	___ Yes ✓ No

Visual Check for "Carryover" in Outlet Airstream:

___ Yes ✓ No

Type: ___ Liquid ___ Suds

Quantity: ___ Trace ___ Other

Subject's Comments: R. B. #5

Shower head could have slightly more pressure and a means of continual flow. Vacuum worked well but perhaps a squeegee blade to assist would be helpful, especially in the corners and door window. suction was extremely good. H_2O temp. was perfect. Bar soap adheres to suction cup bracket handily.

TECHNICAL MONITOR - Nick Lance

Table 1

TEST PARAMETERS

Date:	1-13-76
Time:	1:18 Start 1:28 Finish
Amount of Water Used:	1930 ml (0.509 gal.)
Amount of Soap Used:	0.8 gr (0.028 oz.)
Type of Soap Used	✓ Bar ___ Liquid
Soap Identification	Safeguard
Air Temp. at Shower Inlet	311°K (100°F) °F
Water Temperature	308-311°K (95-100°F) °F
Hair Washed:	___ Yes ✓ No

Visual Check for "Carryover" in Outlet Airstream:

___ Yes ✓ No

Type: ___ Liquid ___ Suds

Quantity: ___ Trace, ___ Other

Subject's Comments: D. G. Shower #6

- Water Temperature was excellent
- Water Collector Nozzle could be bigger - but also allow for curved corners.
- Spray from water nozzle at just the right velocity.

TECHNICAL MONITOR - Nick Lance

Table I

TEST PARAMETERS

Date: 1-13-76

Time: 1:39 Start 1:47 Finish

Amount of Water Used: 1400 ml (0.369 gal.)

Amount of Soap Used: 0.9 gr (0.031 oz.)

Type of Soap Used ✓ Bar ____ Liquid

Soap Identification Safeguard

Air Temp. at Shower Inlet 311°K (120°F) °F

Water Temperature 308-311°K (95-100°F) °F

Hair Washed: ____ Yes ✓ No

Visual Check for "Carryover" in Outlet Airstream:

____ Yes ✓ No

Type: ____ Liquid ____ Suds

Quantity: ____ Trace ____ Other

Subject's Comments: R. L. Shower #7

- Water not warm enough
- Spent most time cleaning shower
- Prefer washcloth

TECHNICAL MONITOR - Nick Lance

Table 1

TEST PARAMETERS

Date: 1-13-76

Time: 2:03 Start 2:11 Finish

Amount of Water Used: 3340 ml (0.882 gal.)

Amount of Soap Used: 1.1 gr (0.038 oz.)

Type of Soap Used ✓ Bar ___ Liquid

Soap Identification IVORY

Air Temp. at Shower Inlet 311°K (100°F) °F

Water Temperature 308 - 311°K (95 - 100°F) °F

Hair Washed: ___ Yes ✓ No

Visual Check for "Carryover" in Outlet Airstream:

___ Yes ✓ No

Type: ___ Liquid ___ Suds

Quantity: ___ Trace ___ Other

Subject's Comments: N.L. Shower #8

- Easier to use the bar soap than liquid soap.
- Took about 1 minute for water to heat up.

TECHNICAL MONITOR- Nick Lance

Table 1

TEST PARAMETERS

Date: 1-13-76

Time: 2:22 Start 2:33 Finish

Amount of Water Used: 1130 ml (0.298 gal.)

Amount of Soap Used: 3.4 gr (0.120 oz.)

Type of Soap Used ✓ Bar ____ Liquid

Soap Identification Safeguard

Air Temp. at Shower Inlet 311°K (100°F) °F

Water Temperature 308-311°K (95-100°F) °F

Hair Washed: ✓ Yes ____ No

Visual Check for "Carryover" in Outlet Airstream:

____ Yes ✓ No

Type: ____ Liquid ____ Suds

Quantity: ____ Trace ____ Other

Subject's Comments: K.B. Shower #9

- Liked suction arrangement for holding bar soap.
- Used enough H_2O though did not feel completely free of soap afterwards. Squeegee worked well. Door opens too easily when wiping. Water felt cool at first warmed up for rinsing. Suction hose came off at wall fitting.

TECHNICAL MONITOR - Nick Lance

Table 1

TEST PARAMETERS

Date: 1-13-76

Time: 2:55 Start 3:03 Finish

Amount of Water Used: 2410 ml (0.636 g

Amount of Soap Used: 1.1 gr (0.039 oz

Type of Soap Used ✓ Bar ____ Liquid

Soap Identification CAMAY

Air Temp. at Shower Inlet 311°K (100°F) °F

Water Temperature 308-311°K (95-100°F) °F

Hair Washed: ✓ Yes ____ No

Visual Check for "Carryover" in Outlet Airstream:

____ Yes ✓ No

Type: ____ Liquid ____ Suds

Quantity: ____ Trace ____ Other

Subject's Comments: E.S. #10

TECHNICAL MONITOR- Nick Lance

C-15

Table 1

TEST PARAMETERS

Date: 1-14-76

Time: 9:20 Start 9:31 Finish

Amount of Water Used: 4260 ml (1.12 gal.

Amount of Soap Used: 15 ml ~~gr~~ (1.125 in^3

Type of Soap Used: ___ Bar ✓ Liquid

Soap Identification: OLIVE LEAF

Air Temp. at Shower Inlet 311°K. (100°F.) °F

Water Temperature 308-311°K (95-100°F.) °F

Hair Washed: ✓ Yes ___ No

Visual Check for "Carryover" in Outlet Airstream:

___ Yes ✓ No

Type: ___ Liquid ___ Suds

Quantity: ___ Trace ___ Other

Subject's Comments: OKH #11

PREFER MIRANOL JEM TO OLIVE LEAF FOR LIQUID SOAP. PICKUP SLIGHTLY CLOGGED MAKING CLEANING FUNCTION DIFFICULT.

ORIGINAL PAGE IS
OF POOR QUALITY

TECHNICAL MONITOR - Nick Lance

Table I

TEST PARAMETERS

Date: 1-14-76

Time: 9:41 Start 9:55 Finish

Amount of Water Used: 5460 ml (1.44 gal.)

Amount of Soap Used: 10 cc ~~gr~~ (0.75 in^3)

Type of Soap Used: ______ Bar ✓ Liquid

Soap Identification: OLIVE LEAF

Air Temp. at Shower Inlet 311 °K (100 °F) °F

Water Temperature 308 - 311 °K (95 - 100 °F) °F

Hair Washed: ✓ Yes ______ No

Visual Check for "Carryover" in Outlet Airstream:

______ Yes ✓ No

Type: ______ Liquid ______ Suds

Quantity: ______ Trace ______ Other

Subject's Comments: BM Shower #12

1. Olive Leaf Soap - acceptable, but prefer more suds for body bathing. Lathered up OK for hair washing. Quantity sufficient
2. Drying in shower was more comfortable.
3. Everything else same as shower on 1-13-76.

TECHNICAL MONITOR - Nick Lance

Table I

TEST PARAMETERS

Date: 1-14-76

Time: 10:02 Start 10:12 Finish

Amount of Water Used: 3160 ml (0.834 gal)

Amount of Soap Used: 8 ml ~~gr~~ (0.6 oz)

Type of Soap Used ____ Bar ✓ Liquid

Soap Identification OLIVE LEAF

Air Temp. at Shower Inlet ____ °F

Water Temperature ____ °F

Hair Washed: ____ Yes ✓ No

Visual Check for "Carryover" in Outlet Airstream:

____ Yes ✓ No

Type: ____ Liquid ____ Suds

Quantity: ____ Trace ____ Other

Subject's Comments: RPR #13

1) PREFER SAFEGUARD BAR TO LIQUID OLIVE LEAF FROM THE CONVENIENCE OF DISPENSING AND SMELL.
2) THE SPRAY NOZZLE COULD BE SET AT A HIGHER FLOW FOR BETTER RINSING.
3) I FELT THE OLIVE LEAF REQUIRED MORE RINSING THAN THE SAFEGUARD. LATHER WAS ACCEPTABLE.
4) CLEANUP OF SHOWER WALLS WOULD BE EASIER IF THE WALLS HAD SHARP CORNERS.

TECHNICAL MONITOR - Nick Lance

Table 1

TEST PARAMETERS

Date: 1-14-76

Time: 10:32 Start 10:47 Finish

Amount of Water Used: 3160 ml (0.835 gal

Amount of Soap Used: 1.7 gr (0.060 oz.

Type of Soap Used ✓ Bar ____ Liquid

Soap Identification Safeguard

Air Temp. at Shower Inlet 311°K (100°F) °F

Water Temperature 308 - 311°K (95-100°F) °F

Hair Washed: ____ Yes ✓ No

Visual Check for "Carryover" in Outlet Airstream:

____ Yes ✓ No

Type: ____ Liquid ____ Suds

Quantity: ____ Trace ____ Other

Subject's Comments: RB Shower #14

Vacuuming seemed easier today, but I guess that is the learning curve taking effect. Water and air temperature good, although water was cold at the very first. I still believe a wider, stronger spray would enable a more clean rinse. I felt that I had a residue left on me until I towel dried.

TECHNICAL MONITOR - Nick Lance

Table 1

TEST PARAMETERS

Date: 1-14-76

Time: 10:59 Start 11:16 Finish

Amount of Water Used: 8cc BRECK; 6260 ml (1.65 gal)

Amount of Soap Used: 1.3 gr (0.045 oz.)

Type of Soap Used ✓ Bar ✓ Liquid

Soap Identification SAFEGUARD (BODY) BRECK (HAIR)

Air Temp. at Shower Inlet ______ °F

Water Temperature ______ °F

Hair Washed: (TWICE) ✓ Yes ______ No

TOWEL USED TO DRY WALLS; WATER AMOUNT 161.1 gr

Visual Check for "Carryover" in Outlet Airstream:

______ Yes ✓ No

Type: ______ Liquid ______ Suds

Quantity: ______ Trace ______ Other

Subject's Comments: JT #15

1) AIR BLOWER HAD A RINGING NOISE UNTIL WATER STARTED PUMPING OUT; THEN NOISE WENT AWAY FOR REMAINDER OF SHOWER.

2) DRYING WALLS WITH DRY TOWEL TOOK 2 MINUTES

3) I SUGGEST THAT FOR A SPACE STATION APPLICATION, THAT THE HOT WATER BE AVAILABLE AS CLOSE TO THE NOZZLE AS POSSIBLE. IT TAKES TOO LONG TO WARM UP THE WATER WITH THIS SET UP.

4) BRECK IS MUCH SUPERIOR TO HARD SOAP FOR WASHING HAIR.

TECHNICAL MONITOR- Nick Lance

Table 1

TEST PARAMETERS

Date: 1-14-76

Time: 13:07 Start 13:23 Finish

Amount of Water Used: 5080 ml (1.34 gal.)

Amount of Soap Used: 0.7 gr. Camay 4 ml ~~gr~~ (Breck)

Type of Soap Used ✓ Bar ✓ Liquid (For hair)

Soap Identification Camay & Breck Shampoo

Air Temp. at Shower Inlet 311°K (100°F) °F

Water Temperature 308-311°K (95-100°F) °F

Hair Washed: ✓ Yes ___ No

Visual Check for "Carryover" in Outlet Airstream:

___ Yes ✓ No

Type: ___ Liquid ___ Suds

Quantity: ___ Trace ___ Other

Subject's Comments: D.G. Shower # 16

Suggestion: Warm air blower at top of shower to help subject dry + water collect at bottom.

TECHNICAL MONITOR - Nick Lance

Table 1

TEST PARAMETERS

Date: 1-14-76

Time: 1:38 Start 1:48 Finish

Amount of Water Used: 2530 ml (0.668 gal.)

Amount of Soap Used: 0.8 gr (0.028 oz.)

Type of Soap Used ✓ Bar ____ Liquid

Soap Identification IVORY

Air Temp. at Shower Inlet 311°K (100°F) °F

Water Temperature 308-311°K (95 - 100°F) °F

Hair Washed: ____ Yes ✓ No

Visual Check for "Carryover" in Outlet Airstream:

____ Yes ✓ No

Type: ____ Liquid ____ Suds

Quantity: ____ Trace ____ Other

Subject's Comments: N.L. Shower # 17

Water took about ½ minute to warm up even though I got into shower relatively quickly after last subject (I guess it was 14 minutes)

TECHNICAL MONITOR - Nick Lance

Table 1

TEST PARAMETERS

Date: 1-14 76

Time: 13:56 Start 14:07 Finish

Amount of Water Used: 1400 ml (0,369 gal)

Amount of Soap Used: 2.4 gr (0,084 oz.)

Type of Soap Used ✓ Bar ___ Liquid

Soap Identification IVORY

Air Temp. at Shower Inlet ___ °F

Water Temperature ___ °F

Hair Washed: ___ Yes ✓ No

Visual Check for "Carryover" in Outlet Airstream:

___ Yes ✓ No

Type: ___ Liquid ___ Suds

Quantity: ___ Trace ___ Other

Subject's Comments: KB #18

WATER WAS COLD UNTIL SUFFICIENT AMOUNT WAS USED TO GET WARM WATER IN LINE.

TECHNICAL MONITOR- Nick Lance

Table 1

TEST PARAMETERS

Date: 1-14-76

Time: 2:16 Start 2:28 Finish

Amount of Water Used: 1240 ml (0.327 gal)

Amount of Soap Used: 1.4 gr (0.049 oz.)

Type of Soap Used: ✓ Bar ____ Liquid

Soap Identification: SAFEGUARD

Air Temp. at Shower Inlet 311°K (100°F) °F

Water Temperature 308-311°K (95-100°F) °F

Hair Washed: ____ Yes ✓ No

Visual Check for "Carryover" in Outlet Airstream:

____ Yes ✓ No

Type: ____ Liquid ____ Suds

Quantity: ____ Trace ____ Other

Subject's Comments: J. T. Shower #19

• Same comments as shower #15.

TECHNICAL MONITOR- Nick Lance

Table 1

TEST PARAMETERS

Date: 1-14-76

Time: 14.35 Start 14:44 Finish

Amount of Water Used: 2380 ml (0.629 gal.)

Amount of Soap Used: 1.6 gr (0.056 oz.)

Type of Soap Used ✓ Bar ____ Liquid

Soap Identification CAMAY

Air Temp. at Shower Inlet ____ °F

Water Temperature ____ °F

Hair Washed: ✓ Yes ____ No

Visual Check for "Carryover" in Outlet Airstream:

____ Yes ✓ No

Type: ____ Liquid ____ Suds

Quantity: ____ Trace ____ Other

Subject's Comments: ES #20

TECHNICAL MONITOR - Nick Lance